IMPERFECT INTERCOOLING AND EFFICIENCY OF COMPRESSION.

By S. B. Redfield.

As the public becomes more and more familiar with compressed air and the losses brought about by poor design and construction, prospective buyers of air compressors are becoming more and more interested in the subject of Intercooling. Most people know that the benefit of compound or stage compression depends upon the intercooling, and that the better the cooling effect the higher the economy, although it is probable that but few have ever taken the trouble to figure out what this actually amounts to. As those who give any thought to the matter usually specify an impossible degree of cooling, it goes to show that they have an exaggerated idea of the facts. In the belief that figures will be interesting and that the clearest way of presenting figures to the mind is by means of diagrams and curves, this problem has been worked out on this plan and the results obtained may serve to make the matter clear.

It can be mathematically proved that with multistage compression to a given pressure, the minimum work will be required when the work is equally divided between the several cylinders, and this occurs when the ratio of compression is alike for the several stages. In this article attention will be confined to compound, or two stage compression, as this is the most usual case.

The effect of poor intercooling is to raise the pressure in the intercooler, and thus to disturb the balance of power between the cylinders. As the intercooling becomes less and less effective, and the intercooler pressure becomes higher and higher, the work of the low pressure cylinder increases. Although at the same time the work of the high pressure cylinder decreases, this does not occur as rapidly as the increase in the work of the low pressure cylinder, and the net result is an increase in the total work done.

To examine the process in detail, turn to the theoretical adiabatic indicator cards, (Fig. 1). These cards are placed one above the other for comparison and lines are drawn through all to show the relative volumes of the high and low pressure cylinders, which are the same for all. The total ratio of compression from atmosphere to 100 lbs. at sea level is 7.8 and in order to make the work equal in both stages of the compound compression, and thus a minimum, the cylinder ratio is made the square root of the total raio, or 2.79. With perfect intercooling this gives the same ratio of compression in each cylinder, and, as before stated, requires the minimum work. In each diagram, the net theoretical saving by compounding is shown by the shaded area. This will be seen to grow less and less as the intercooling becomes less effective.

The upper card shows perfect intercooling, equal horse power in the two stages and minimum total horse power. Starting with 60 degrees, F., in each cylinder, the maximum temperature attained by compression in each stage is 240 degrees. The intercooling being perfect, the temperature of the inlet to the high pressure cylinder being the same as that to the low pressure cylinder, the pressure in the intercooler, or inlet to high pressure cylinder, is that corresponding to the isothermal curve, or 26.3 lbs. per square inch. This is of course obtained by multiplying the absolute intake pressure, 14.7, by the cylinder ratio, 2.79, giving 41 lb., absolute, or 26.3 lbs., gage. This gives 7.7 I. H. P. in each stage, or 15.4 total per 100 cu. ft. per minute.

Passing to the second theoretical indicator card, this shows the result when the intercooling fails to reach perfect conditions, by 150 degrees. In other words, the temperature of the inlet to the high pressure cylinder is now 210 degrees, instead of 60, which is an excess of 150 degrees. Under these conditions, the volume of the high pressure cylinder necessarily remaining constant, the intercooler pressure must rise, in order to take care of the air. The pressure will rise in direct proportion to the absolute temperature. This will be $41 \times \dfrac{210+461}{60+461} = 52.8$ lbs., absolute, or 38.1 lbs., gage, as shown.

The adiabatic compression line meets this new intercooler pressure line at a higher point than before, and the temperature corresponding to this point, or the maximum low pressure cylinder temperature, is now 292 degrees. This is an increase of 52 degrees above that obtained with perfect intercooling, which was shown to be 240 degrees.

Commencing to compress in the high pressure cylinder, at 38.1 lbs, pressure and 210 degrees, the final temperature attained with adiabatic compression to 100 lbs. is now 376 degrees as shown on the diagram. This is an increase of 136 degrees above that obtained with perfect intercooling.

Under these conditions, although the horse power in the high pressure cylinder has decreased to 7.21 from 7.7, the horse power of the low pressure cylinder has increased to 9.95, from the same figure. This gives a total of 17.16 I. H. P. per 100 cubic feet per minute, instead of 15.4, the figure for perfect intercooling. The diagram clearly shows the decrease in the shaded area, or the theoretical net saving by compounding.

From both these diagrams it will be seen that the line of adiabatic compression in the low pressure cylinder, if extended, would meet the line indicating the volume of the high pressure cylinder at a point corresponding to a temperature of 332 degrees. If there were no intercooling at all, the air would enter the high pressure clyinder at this temperature, and the pressure would have to be 47.7 lbs. gage. All this is shown in the third or lowest diagram, which represents the conditions resulting from no intercooling, or an excess of 272 degrees over perfect intercooling.
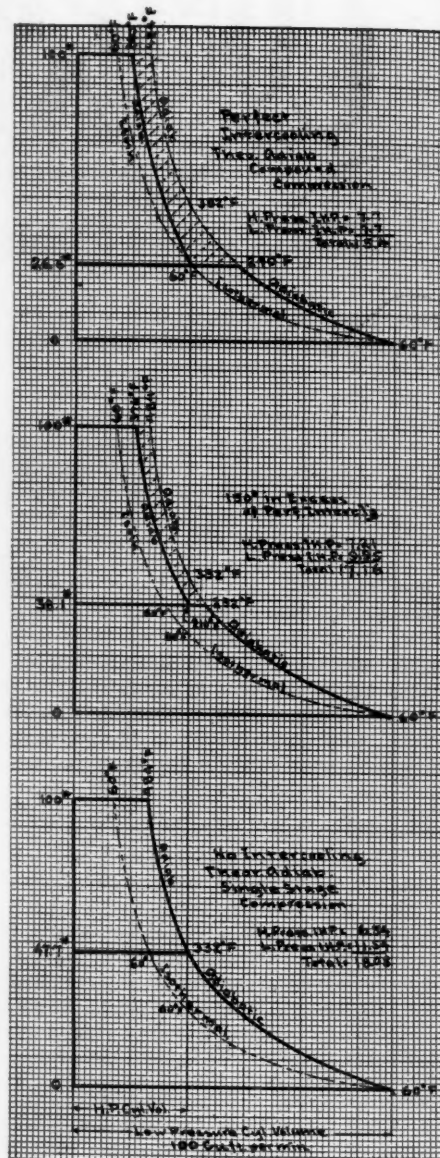

FIG. I—DIFFERENT RATES OF INTERCOOLING.

The compression line of the high pressure cylinder starts in where that of the low pressure cylinder left off, and the line is continuous. The result of this is a final compression temperature of 484 degrees at 100 lbs. pressure, and while the horse power in the high pressure cylinder has decreased to 6.54, that of the low pressure cylinder has again increased and is
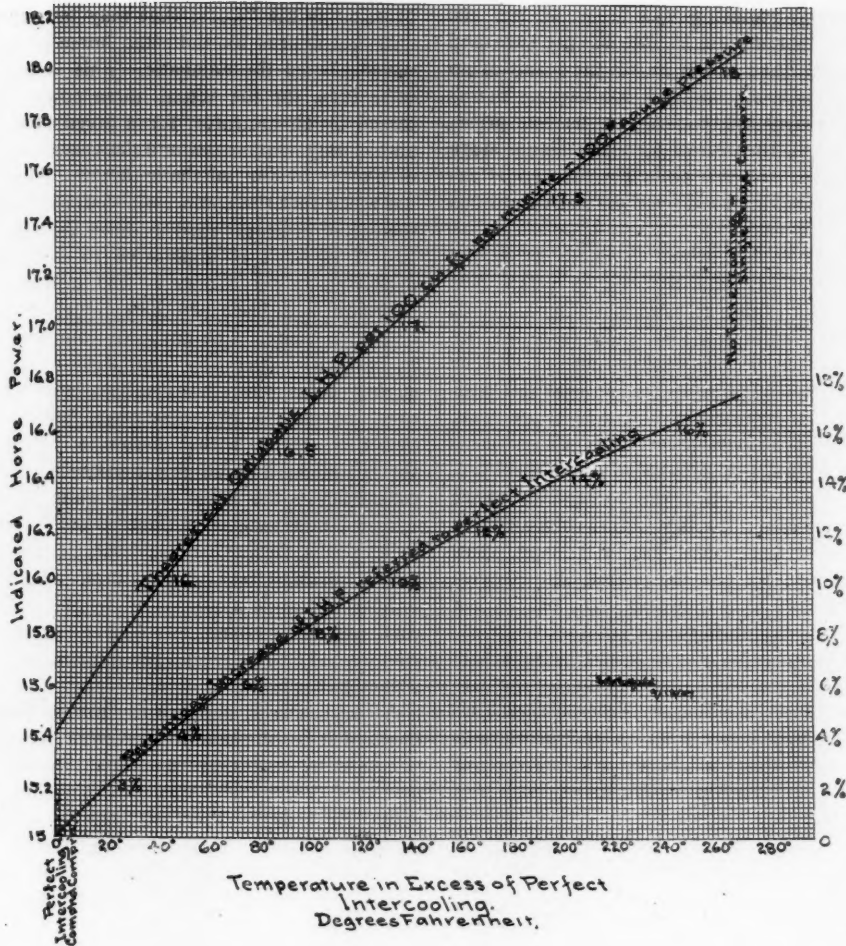
FIG. II.

now 11.54, making a total of 18.08 I. H. P. per 100 cubic feet per minute to 100 lbs. pressure. This is now nothing more than single stage adiabatic compression, and the theoretical horse power is that corresponding to single stage compression to 100 lbs. pressure. Here, the saving by compounding has of course entirely disappeared, and the work might as well have been done in one cylinder.

In order to show the result upon the power of progressive falling off in intercooling effect, two sets of curves are given in Fig. 2 showing the total theoretical adiabatic I. H. P. per 100 cubic feet per minute to 100 lbs. gage, and also the percentage increase in power, referred to perfect intercooling, as the intercooling becomes poorer. In this diagram the vertical

distances represent I. H. P. for the one curve and percentages for the other, while the horizontal distances represent excess of temperature of high pressure cylinder intake, over that of perfect intercooling. Take, for example, the point marked 100 degrees; this means that the temperature of the air leaving the intercooler and entering the high pressure cylinder is 100 degrees in excess of perfect cooling, which would be 60 degrees, and it is therefore 160 degrees. At this point, the total indicated horse power per 100 cubic feet per minute to 100 lbs. gage is shown to be 16.69, and the increase over that for perfect intercooling is 8.3 per cent.

At the left of these curves is shown the result of compound compression with perfect

intercooling, requiring 15.4 I. H. P. per 100 cubic feet per minute to 100 lbs. pressure and at the right hand end is shown the result of no intercooling at all, which is 272 degrees in excess of perfect intercooling, or, as was previously shown, theoretical adiabatic single stage compression. At this point the theoretical excess of power required over perfect conditions is 17.4 per cent.

Fig. 3 shows the variation in the horse power in each cylinder and the rise in intercooler pressure as the degree of intercooling falls off. The curves show at a glance the result of any partial degree of intercooling, and it will be seen that the increase of power required with 20 degrees excess of temperature is 2 per cent., and with 40 degrees excess it is 3.7 per cent. Of course, as the maximum theoretical increase of power due to no intercooling at all is 17.4 per cent., the first figure represents a loss of 2 in a possible 17.4, or 11.5 per cent. of maximum loss, and the second figure represents a loss of 3.7 in a possible 17.4 or 21.3 per cent. of the maximum theoretical loss.

When possessed of these figures the prospective compressor buyer will jump to the extreme and call loudly for "more cooler surface," and will insert into his specifications a clause calling for a degree of intercooling which the manufacturers know is practically impossible.

The word "practically" is full of import, for it is the practical results that mean dollars and cents, and it is the latter which interest the public. This being the case, and it having been repeatedly stated that these diagrams are theoretical, nothing would be more desirable than to interpret these theoretical figures into practical ones, and at the same time to show that while the public often demands impossibilities in one direction, other and important features, which are not only possible, but practical, and mean material saving, are never mentioned.

The particular subject meant by the above is what is known as "Efficiency of Compression" and it must be admitted that the term is seldom used by the buying public, either in conversation or in specifications. Nevertheless, this efficiency of compression is a most important subject, especially as, unlike the subject of intercooling, great improvements are possible and practicable by suitable design.

It is sometimes thought that adiabatic compression is the "worst that may be expected" and that figures for indicated horse power can never exceed the adiabatic. This is indeed a false idea, for the actual horse power as obtained by an indicator, for a given amount of air actually compressed and delivered, is always in excess of the adiabatic figure. This does not mean that the compression curve shown on the actual indicator card is above the adiabatic, for, if it is, it is imperative to look at the discharge valves at once to find, and stop, the enormous leak back into the cylinder that must be taking place. The curve of compression in a correctly operating compressor will be slightly below the adiabatic line, but owing to the "humps" in the discharge line, due to throttling through the discharge valves, the actual indicated horse power exceeds the theoretical figure, the latter not including "humps."

The "Efficiency of Compression," referred to adiabatic figures, is the ratio of the theoretical adiabatic I. H. P. per hundred cu. ft. per minute to the actual I. H. P. by the indicator card per hundred cu. ft. of free air actually compressed and delivered per minute, including volumetric efficiency.

As an example, suppose the piston displacement of a certain compressor were 108 cu. ft. per minute, and that the card showed $92\frac{1}{2}$ per cent. volumetric efficiency, and that the actual I. H. P. by the card was 18, with 100 lbs. gage pressure, compound compression. This would mean that $92\frac{1}{2}$ per cent. of 108, or 100 cu. ft. per minute, was actually compressed and delivered and that the actual I. H. P. developed in compressing this 100 cu. ft. of air was 18. The theoretical adiabatic I. H. P. per 100 cu. ft. per minute actually compressed and delivered by compound compression to 100 lbs. is 15.4. The efficiency of compression then is 15.4 divided by 18, or 85.5 per cent. This figure appears low, and it really is low compared to what some first class manufacturers are now doing. It is probable, however, that there are more compressors with 85.5 per cent. or less efficiency of compression than there are with higher; and yet the public never says a word about it, but devotes its attention to impossible degrees of intercooling, which call for absolutely uneconomical areas of cooling surface and rivers of cooling water.

This efficiency of compression, with ample valve and passage area, may come up to as high as 93 to 94 per cent. for compound com-

Temperature in Excess of Perfect
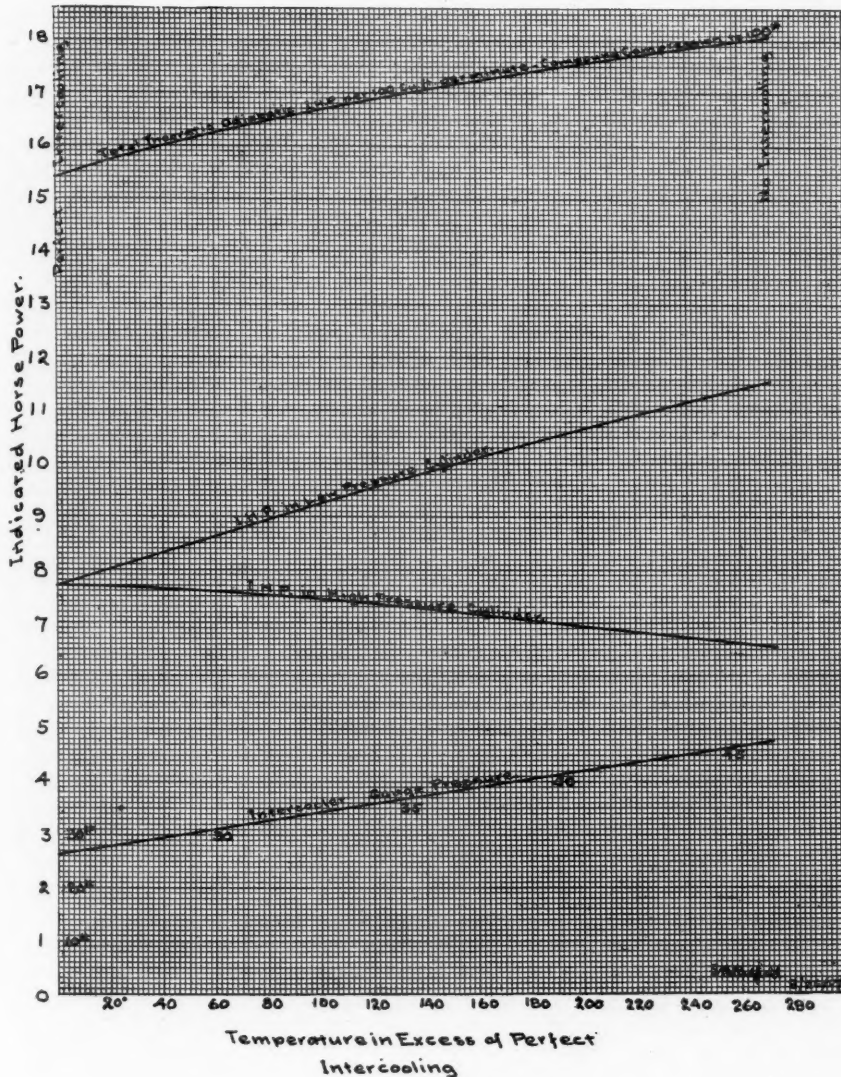Intercooling

FIG. III

pression to 100 lbs. The losses involved are due to two main causes—defective intercooling and contracted valve and passage area. In order to separate these two causes of loss, assume a practical case, and as an average figure let the efficiency of compression be 90 per cent., and let the intercooling be within 40 degrees of perfect, both of which figures are fair assumptions. The latter figure means that the temperature of the air leaving the intercooler and entering the high pressure cylinder is 40 de-

grees higher than that entering the low pressure cylinder. Referring to the curves, this would mean an excess of I. H. P. of 3.7 per cent. over that obtained with perfect intercooling.

If the efficiency of compression is 90 per cent., the actual I. H. P. per 100 cu. ft. per minute must be 17.1 A glance at the curve for I. H. P. will show that 40 degrees excess temperature should require 15.97 I. H. P. per 100 cu. ft. This means that the difference be-

tween 15.4 and 15.97, or .57 horse power, has been lost from imperfect intercooling, and the rest, or the difference between 15.97 and 17.1, or 1.13 horse power, has been lost on account ·of insufficient valve area. To go to percentage: .57 is 3.7 per cent. of 15.4, as shown by the curve, and 1.13 is 7.34 per cent. of 15.4. As a fairer comparison would be the percentage referred to the actual horse power obtained, it is best to say .57 is 3.33 per cent. of 17.1 and 1.13 is 6.6 per cent. of 17.1. This shows that the loss by contracted valve area is in this case almost exactly twice as great as that due to poor intercooling.

As beforesaid, with first class practice, the efficiency of compression may be as high as 93 to 94 per cent. for compound compression to 100 lbs. Taking 94 per cent., the actual I. H. P. per hundred cu. ft. per minute to 100 lbs. will be 15.4 divided by .94, or 16.4, making a total loss of only one horse power, over and above the theoretical.

Again, assuming 40 degrees excess of temperature over perfect intercooling, the loss due to imperfect intercooling is again .57 horse power, which leaves the remainder, or .43 horse power, to be chargeable to throttling through valves and passages. .57 is 3.48 per cent. of 16.4, and .43 is 2.62 per cent. of 16.4, the actual power required. Now it is seen that with proper valve and passage areas, the loss due to throttling is even less than that due to poor intercooling.

What is more interesting still than this fact is, that the actual H. P. per hundred cu. ft. per minute has been reduced from 17.1, the figure with 90 per cent. efficiency of compression, to 16.4 with 94 per cent. This makes the net saving in power .70 I. H. P. per 100 cu. ft. per minute, which is over 20 per cent. more than .57 I. H. P., the total loss by inefficient cooling with 40 degrees excess of temperature, which latter is not the best a commercial intercooler can do.

From the foregoing arguments, it will be clear that although the buying public should not forget the subject of intercooling, as this is a very important item, it would be highly advisable to put it into its proper relative position and to look more carefully into the equally important, but often overlooked, subject of valve and passage area and the efficiency of compression.
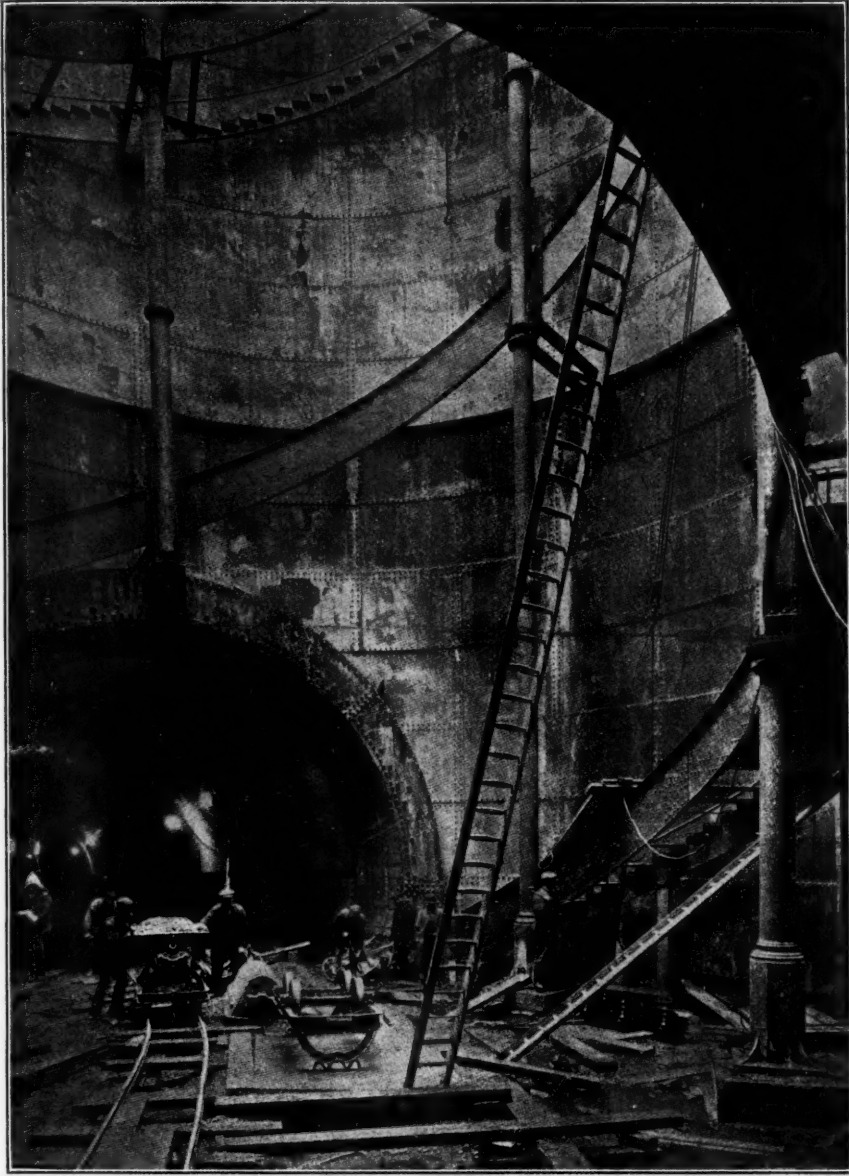
THE ROTHERHITHE TUNNEL AND SUBWAY

A new Thomes tunnel for fast passengers and vehicles, connecting Rotherhithe on the South and Steping on the north bank, begun four years ago, is fast approaching completion and in fact may be ready for opening when these lines come to the reader. Strictly speaking, the readers of *Compressed Air* have no business with this work, since compressed air was not employed in its construction, but the tunnel habit which compressed air has begotten leads to interest in all modes of construction and all subterranean and subaqueous engineering. This is practically a new London highway usefully supplementing the Tower Bridge and the Blackwall Tunnel and relieving the congested traffic in this very crowded and busy section.

The roadway begins with an open approach, an inclined cutting 900 feet long with an entrance arch and concrete walls. The roadway will be 16 feet wide with a foot pavement on each side 6 feet wide. Before entering the cut and cover section the East London Railway is crossed by a steel plate girder bridge, stairways in the side walls giving easy access to the roads above and to the railway station. The land tunnel is circular with an inside diameter of 27 feet and constructed of five rings of brickwork. At the end of this tunnel is shaft No. 1, the base of which is 70 feet below ground level. The shaft is double lined with steel plates, the space between being filled with concrete, and it has an inspection gallery running around at the top. At this point the cast-iron circular tunnel begins, the opening being finished with a grey granite moulding. This portion has an outside diameter of 30 feet and the inside diameter of 27 feet. The rings have a uniform width of 30 inches on the straight sections, each ring having 16 sections and a key. Inside the iron is covered with concrete lined with white glazed tiles.

Shaft No. 2 is much like the first, but is 102 feet below ground level and is fitted with a wide spiral staircase for public use, the stairs being supported on their inner ends by cast iron pillars. This shaft will be covered with a glazed roof.

The subaqueous section, the invert of which is 80 feet below high water level, is 1,500 feet long and ends in shaft No. 3 which is at the

SHAFT No. 3 ROTHERHITHE TUNNEL.

other bank of the river. This shaft, shown in the half tone, is practically a duplicate of shaft No. 2, with similar spiral staircase and glazed domed roof. Between this and shaft No. 4 there is a distance of a little more than 1,150 feet, the tunnel being driven to a curve of 800 feet radius. This is probably a unique instance of an iron lined tunnel with such a sharp curve. From shaft No. 4 there is another section of cut-and-cover work, followed by 1,200 feet of open approach, making the total length about a mile and a quarter.

Under the whole length of the cut-and-cover and the cast iron tunnels a subway has been

built, having a brick arch and concrete base and sides. It has a width of 13 ft. 6 in., and a headway in the middle of 6 ft. 6 in. It is ventilated by grids in the roadway, has an open channel down the middle for drainage purposes, and is entered from manholes at the shafts and at the ends of the open approaches. This subway is intended to accommodate pipes, cables, etc.

Two shields were used, being lowered down shaft No. 3, one driving south under water and land and being broken up when it reached shaft No. 1, the other having only a short course in the other direction to shaft 4. A pilot tunnel was driven under the river before the tunnel proper by a special form of excavating machine, the soil being removed by trucks.

COMPRESSED AIR CALCULATIONS*

By E. A. Rix, Mem. Am. Soc. C. E., Mem Am. Soc. M. E.

Fellow Students:

The great progress in the Arts and Sciences is made for commercial reasons and by people who are seeking either gain or a livelihood. The trade catalogue is one means by which advance information is given the public, and in it the data and tables and scientific information are mostly theoretical. It is not considered prudent by business men to take the public into their confidence and give them the practical co-efficients which have cost years, much money, and hard work to acquire. For this reason, catalogue information is ofttimes very misleading, and is valuable only as a means of comparison.

No matter what theoretical engineering course we take, to be valuable to the community we must all take a post-graduate course of experience and become *commercial engineers.* The sooner we reach that degree, the better for ourselves and for everybody concerned. Theoretically and actually, you may have a million dollar ore body, but if it costs more per ton to realize its value than it yields commercially, there is not a cent in that ore-body. That, after all, is the only fact we

*Published by courtesy of Mining Association of the University of California, before whom this paper was read February 19, 1908.

wish to know, and we want to know it beyond a peradventure.

It seems to me, therefore, that if I am honest in my desire to help you, I must loosen up and give you practical, commercial co-efficients, show you how we safeguard our own interests, and at the same time satisfy those with whom we deal. And finally, it seems to be about the best way in which one can repay this University for the benefits which he has received from a four-years' training.

Before we undertake to solve a problem which I shall present for your consideration, I shall give you some of the practical data which I use to make these calculations.

During the last twenty years, I have kept a log of all the compressed air plants I have tested, and also the actual performance of a great number, covering almost every kind of compressor and compressed air motor or tool, and I have averaged all the indicator cards taken from the various compressors used in mining work and compared the indicated horse-power with the actual power required. Comparing this with the displacement of the compressor cylinders, I have concluded that for a safe and sane power factor, we must allow 20 horse-power for every one hundred cubic feet of cylinder displacement, to compress air from atmospheric pressure to 90 or 95 lbs. receiver gauge pressure at sea level.

I have made my calculations on these pressures because they are the standard pressures now used for pneumatic work, and nearly every machine and motor is constructed for these pressures. Twenty horse-power means brake horse-power, i. e., the power delivered at the shaft of the prime mover.

If you consult tables in any engineering magazine or trade catalogue, on air compressors, you will note that the power claimed to do certain work is much less than the figure which I give you, and in explanation, it must be noted that these tables are theoretical, and do not take into account the mechanical efficiency of the compressor, nor losses due to volumetric efficieny of compressors. These figures are therefore misleading, and should be avoided except to use as comparisons between one machine and another.

It is most unfortunate that the public is not given the results of working tests upon plants of all descriptions running under ordinary conditions, as such information is much more val-

uable than the records of official tests, which are usually made under special conditions by experts at the most satisfactory load—a set of conditions not often realized.

You must have a safe margin in your calculations so that neither you nor those for whom you are installing a plant will be disappointed, and I, therefore, have given you 20 horse-power per one hundred cubic feet of cylinder displacement as a figure that will never get you into trouble, and at the same time, it is not too generous. It may also be noted that it would be just as well in small plants to make no distinction between single and two stage machines. By small plants, I mean up to 400 cubic feet per minute capacity.

Second.—Remember that a compressed air cylinder will never give a quantity of air equal to the volume swept by the piston, for the reason that such things as clearance, leakage, temperature, piston speed, etc., reduce the theoretical quantity, so that it is best to figure about 80 per cent. volumetric efficiency for the average mining compressor. Many do not give 60 per cent. and some give 90 per cent.

Third.—In using compressed air at 90 lbs. pressure cold, it will take 24 cubic feet of free air per minute to give one horse-power in plain slide valve engines, and 15 cubic feet with good expansion valve gearing, and between these two limits will lie all the various types of engines. If the air be reheated, to about 300 degrees Fahrenheit, it will reduce the above quantities about one-third. In one hoisting engine which we installed, having compound Corliss cylinders, and where the air was heated to 400 degrees Fahrenheit before entering each cylinder, it required between 7 and 8 cubic feet only for one horse-power. Most mines, however, use cold air and prefer the power loss to the trouble and expense of the installation and maintenance of reheating apparatus.

Fourth.—The tables set forth in the trades catalogues for the air consumption of standard piston rock drills are fairly accurate and are generally in terms of the compressor cylinder displacement.

Fifth.—For operating ordinary station and sinking pumps of the direct acting type, which is the ordinary stock pump usually used in mining operations, it will be safe for you to calculate that one cubic foot of free air com-

pressed to ninety pounds gauge pressure will do 135 foot gallons of pumping.

Sixth.—That ordinary mining hoists have a mechanical efficiency of about 75 per cent.

Seventh.—For the determination of pipe sizes, losses of pressure and terminal pressures for compressed air transmission, I use the Johnson formula, which is very satisfactory:

$$P_1^2 - P_2^2 = \frac{.0006V^2L}{A^5}$$

Wherein P_1=absolute initial air pressure
P_2=   ”   terminal air pressure
V=free air equivalent passing through the pipe.
L=length of pipe in feet.
A=diameter in inches.

This formula is quite simple to solve.

With these facts at hand, we can now rapidly calculate the problem we shall consider as follows:

PROBLEM.

A mine having a water power distant 5,000 feet wishes to generate compressed air and transmit it to the collar of the shaft for operating purposes. The work to be performed is as follows:

100 tons of ore and waste to be hoisted in 20 hours.

30 gallons of water per minute to be pumped either at a station or a sinking pump.

5—2¼ standard piston rock drills to be operated.

3 air hammer drills to be operated.

General Conditions:

Depth of shaft, 600 feet.

Weight of skip and rope, 1,000 lbs.

Weight of ore hoisted, 1 ton.

Initial air pressure, 95 lbs.

Final air pressure, 90 lbs.

Altitude, sea level.

Geared hoist and unbalanced hoisting.

Required:

Size of compressor.

Diameter of air pipe.

Brake horse-power.

Altitude factors.

Re-heating co-efficients.

Note.—In problems of this kind, we must reduce all of our requirements to cubic feet of free air, because free air is the basis for all power calculations.

To determine the free air required for hoisting: If 100 tons of ore and waste are to be hoisted in 20 hours, the hoisting will be done at the rate of 5 tons per hour, and inasmuch as each load hoisted contains one ton, it follows that there will be a load hoisted every 12 minutes. Of course, we know that an absolute schedule of 12 minutes between hoists can scarcely ever be carried out, for the intervals may be shorter during one hour and longer during another, or stop altogether, but the only way to figure it is on a regular basis, and after that is determined, allowance one way or another can be made for any irregularity.

The load being 2,000 lbs. of material and 1,000 lbs. of rope and skip, makes a total of 3,000 lbs. which is to be hoisted 600 feet. 3,000 lbs. lifted 600 feet will require 1,800,000 foot pounds of work, or 54 horse-power, theoretical. Inasmuch as the hoist has a probable efficiency of 75 per cent., the 54 theoretical horse-power becomes 72 brake horse-power actually required.

Using cold air, it requires, as we have mentioned before, 24 cubic feet of free air per horse-power. Then $24 \times 72 = 1,728$ cubic feet of free air which the hoist will consume to make one lift. This, you will note, gives us direct results without taking into consideration the element of time or the dimensions of the hoist. If we made a hoist every 12 minutes, and it required 1,728 cubic feet to make a hoist, then the compressor must furnish 144 cubic feet of free air per minute continuously, and we must have storage capacity sufficient to accumulate the air between hoists. Right here is the vital point of hoisting economically with compressed air.

Let us assume in our problem that we hoist at the rate of 300 feet per minute, then it will take two minutes to make the lift, and the hoist will be lowering and idle during the next ten minutes. During this ten minutes, the compressor is delivering 144 cubic feet of free air per minute, or, 1,440 cubic feet total, which must be stored.

If the hoist is none too large for the work, you will find that if the pressure in the receiver drops more than one atmosphere or from 90 lbs. to 75 lbs., that the hoist will not operate in a satisfactory manner. Then, in our problem, if we must draw 1,440 cubic feet from the receivers at a drop of one atmosphere in pressure, the receivers must have a cubic capacity of 1,440 cubic feet, and if the hoist is amply large so that it will still operate after the receiver pressure has dropped two atmospheres, or from 90 lbs. to 60 lbs., then the receiver capacity can be one-half of 1,440 or 720 cubic feet, but it is not wise to go below this pressure, because it will affect too materially the pressure required for operating the other machinery.

For a first class job, install receivers having a capacity equal to the storage required at one atmosphere pressure. Right here let me say that large receivers cost less in proportion to their storage capacity than small ones. For example: A carload consisting of four receivers 54 inches in diameter by 30 feet long, containing about 2,000 cubic feet, costs at the present time about $1,600, while the same storage in ordinary receivers 48 inches in diameter and 12 feet long, would cost about $2,200. It is better to invest more money in receivers and less in compressors, because the smaller compressor takes less power at the peak, and most power bills are figured on a constant peak.

If you install a plant and the receiver capacity is too small, you can always determine the proper quantity of storage by running the compressor with the unloader cut off, and if the receivers blow off between hoists and the pressure drops more than 15 pounds during hoisting, add more receiver capacity until it will not blow off nor drop more than 15 pounds. If you arrive at the point where it does not blow off and the pressure does not fall to 15 pounds, then slow down the compressor until the desired drop is reached, and you will be operating your plant at the most economical point. Then cut in the unloader again and let it work when it will. An unloader only saves wear and tear in the compressor where you buy power at the peak load, as happens in most cases, but does not affect your power bill.

Let us go back now to our problem. We find, therefore, that 144 cubic feet per minute is required for hoisting. Now, while we have allowed four hours in twenty-four, or an hour and twenty minutes on each shift for hoisting and lowering men, timbers, supplies, etc., it is entirely probable that at least once every hour some one will be going up and down the shaft, and it would be practical, therefore, to say that the hoist would handle

six loads per hour instead of five, and we must therefore add twenty per cent to the hoisting requirements, making, say, 175 cubic feet instead of 144.

To determine the amount of compressed air required for pumping: For pumping 30 gallons per minute 600 feet, requires 30x600 or 18,000 foot gallons of work. If one cubic foot of free air at 90 pounds gauge pressure will give 135 foot gallons of work, we shall require 133 cubic feet of free air for the pumping. This requirement is constant.

To determine the amount of compressed air required for drilling: Five 2¼-inch rock drills will require 50 feet of free air each, or 250 cubic feet, and three air-hammer drills will require 25 cubic feet each, or 75 cubic feet. To get these amounts, take about eighty per cent. of the requirements as stated in rock-drill catalogues, which always give quantities in compressor-cylinder displacement which do not deliver on an average within twenty per cent. of their displacement, excepting in large machines.

Our total requirements will therefore be:

Hoisting	....	175 cubic feet
Pumping	....	133 cubic feet
Drilling	....	325 cubic feet
Total	....	633 cubic feet

This 633 cubic feet does not take into consideration any ordinary pipe leakage in the hoisting works and below ground, and in conducting this air from a distance, inasmuch as our problem calls for a transmission of 5,000 feet, it would be well to allow a leakage of five per cent. on the entire system. This would bring our requirement up to 665 cubic feet, and if we allow that our compressor will give a volumetric efficiency of at least eighty per cent., we must have a cylinder displacement of 830 cubic feet per minute.

You will remember that our power factor was 20 horse-power per 100 cubic feet; consequently we must have 166 horse-power delivered on our water-wheel shaft to drive this compressor.

Finally, we must determine the size of the pipe, allowing five pounds drop in pressure for friction loss. You will remember the formula.

$$P_1^2 - P_2^2 = \frac{.0006 V^2 L}{A^5}$$

P_1 the initial pressure absolute$=95+14.7$ or 109.7, and its square is 12,034.

P_2 the terminal pressure we have stated shall be 5 pounds less than the initial or 90 pounds, of 104.7 absolute and its square is 10,962.

The difference between these two, or—

$$P_1^2 - P_2^2 = 1072.$$

Substituting this in our equation, and also the values for L and V, we have—

$$1072. = \frac{6 \times 5000 \times 633 \times 633}{10000 \times A^5}$$

Reducing, we have $1072 \times A^5 = 3 \times 633^2$, or $A^5 = 1121$

$A = 4$-in. pipe.

We have now to figure the size of the compressor required. If you happen to have tables and catalogues at hand, it will be an easy matter to look up a satisfactory compressor having a displacement of 830 cubic feet, but if such literature is not at hand, the size of the compressor may be determined as follows:

It almost goes without saying that you would select a two-stage compressor for anything over 400 cubic feet capacity. This two-stage compressor will have a low-pressure or gathering cylinder, wherein the air is compressed to about 25 pounds, and a high-pressure cylinder where the air at 25 pounds after it has been cooled will be compressed to 90 or 95 pounds pressure. The reason a two-stage machine is selected is because it has a higher volumetric efficiency, requires less power to operate it, is easier to lubricate on account of low temperatures and has less strains on the mechanism.

The first thing to consider is the speed at which you will operate the compressor, and this will be dictated by many things. If you have a limited amount to expend, you will naturally select as high a working speed as possible, because the higher the speed, the smaller the compressor.

Again, you may have to take the future into consideration, and you may want more air later on, as the shaft goes deeper or more water is encountered. You would then naturally select such a speed as would give you the margin of additional power required.

You may take 150 revolutions per minute as

the maximum for compressors from 400 to 1,500 feet capacity, and 100 revolutions per minute as a speed that will give you a fifty per cent. margin for the future, so let us assume that the mine in question has a future, and take 100 revolutions per minute. If our requirement is 830 cubic feet per minute we shall then require an intake or compression cylinder which will give us 8.3 cubic feet per revolution, and inasmuch as the cylinder is double-acting—that is to say, makes two displacements per revolution, the cylinder must have a cubic capacity of 4.15 cubic feet.

Experience dictates that the average compressor cylinder is built for the following strokes and capacities:

6-in. stroke up to 50-ft. capacity
8-in. " " 100-ft. "
10-in. " " 200-ft. "
12-in. " " 500-ft. "
16-in. " " 700-ft. "
18-in. " " 1500-ft. "
24-in. " " 2500-ft. "

Our compressor will therefore be best suited by an 18-inch stroke, or 1.5 feet. If the capacity is 4.15 cubic feet and the stroke 1.5 feet, the area of the cylinder will be $\dfrac{4.15}{1.5} = 2.75$ square feet or 397 square inches, which is the area of a 22¼-inch cylinder. The low-pressure cylinder will therefore be 22¼×18.

It is very evident that if we have two cylinders to do our compressing, there is no good reason why one cylinder should do more work than the other, and there is a very good reason why the work performed by these cylinders should be equal, viz: because the total work and temperature developed will be at a minumum, just why would lead us into mathematics, and so you must take the statement as a fact.

There is also the mechanical reason that the strains on the machine will be at a minimum, and if you construct the compressor of the duplex type, both sides will be alike, except as to the cylinders. It can be easily shown by algebraic method that if our two cylinders perform equal work, the intermediate pressure must be a mean proportional between the initial absolute pressure and the final absolute pressure, and the cylinder ratios will be as the ratios of either the high or initial absolute pressure to the intermediate. In other words, to put this in such shape that you will easily remember it,

If P = absolute initial pressure
P_1 = absolute intermediate pressure
P_{11} = absolute final pressure

then $P_1 = \sqrt{P \times P_{11}}$

Take our example: Our initial pressure is atmospheric, or 147 absolute. Our final pressure is 95 pounds gauge, or 109.7 absolute. The intermediate pressure will then be $P_1 = \sqrt{14.7 \times 109.7}$ or 40 pounds absolute = 25.3 pounds gauge pressure. Our proportion then stands 14.7:40::40:109.7, which represents a ratio of

$$\frac{40}{14.7} \text{ to } \frac{109.7}{14.7} = 2.74$$

The cylinder ratios will therefore be indentical with the pressure ratios, and our high-pressure cylinder will have a capacity of $\dfrac{1}{2.74}$ of the low pressure. The strokes being the same, the area of the high pressure cylinder will be $\dfrac{1}{2.74}$ of the low pressure, which was 397 square inches. Dividing this by 2.74, we have 145 square inches as the area of the high-pressure cylinder. This corresponds to a diameter of 13½ inches. The compressor will then be a 22½-inch×13½-inch×18inch stroke, and you will be justified in taking the nearest size to this that the manufacturers can supply.

You will note that as the altitude increases, the initial absolute pressure diminishes, and as the final pressure remains the same, the pressure ratio grows larger as the altitude increases. For example: At 10,000 feet the atmospheric pressure is ten pounds, instead of 14.7 pounds, and if you go through the same calculations that we have just made, you will find that the cylinder ratios will be 3.3 instead of 2.74, and this will make the high-pressure cylinder only 12½ inches in diameter instead of 13½ inches in diameter, and the intermediate pressure will be 18.3 pounds instead of 25.3 pounds. Such a compressor would not, however, be able to do the work contemplated in the problem we have considered, for the reason that while the weight of air necessary to do work re-

mains practically the same for reasonable altitudes, the capacity of the compressor diminishes as the altitude increases. It is true the volume remains the same, but it has not the weight and therefore you must increase the size of the cylinder required at sea level by the ratio between the ratio of compression at sea level and the ratio of compression at altitude.

In our problem, the ratio of compression at sea level is 7.5 and the ratio of compression at altitude of 10,000 feet is 11. The sea level compressor must be increased therefore,

$\dfrac{11}{7.5}$ or 1.47 times, to give the same weight

of compressed air at 10,000 feet altitude, or, to put it even more simply, it will take 11 strokes of the same-sized compressor piston at 10,000 feet altitude to give the same compressed air or to do the same work as 7½ strokes will do at sea level.

In our problem this would make a low-pressure cylinder of 27 inches instead of 22½ inches, and a high-pressure cylinder of 15 inches instead of 13½ inches. In other words, this altitude compressor is nearly fifty per cent. larger to do the same work.

A proper understanding of these simple calculations will enable you to check up compressor sizes and proportions, and no one could furnish you with a sea level compressor for an altitude one, and *vice versa*. We have assumed eighty per cent. volumetric efficiency in this problem, but if the compressor happens to be a slow-speed, mechanical-valve machine, ninety per cent. could be assumed. The figures I have given you are safe, and taken from average plants, and it will be necessary for you to use your judgement is assuming a higher or lower factor.

To determine the amount of compressed air required for re-heating: It is practical to re-heat air from 300 to 400 degrees Fahrenheit in various ways and great economy realized, especially for pumping and hoisting, and if it is possible you may reduce the quantities of cold air which we have figured for this work by the ratio of the atmosphere to the compressed air temperature absolute. Thus, if the atmosphere is at 60 degrees Fahrenheit, or 520 degrees absolute, and the compressed air is used at 300 degress Fahrenheit, or 760

degrees absolute, then the cold air volume for your work may be taken at the ratio of $\dfrac{520}{760}$, or about seventy per cent., thus making a saving of thirty per cent.

In conclusion, let me caution you about being led astray by that Will-o'-the-Wisp, "Efficiency." When you come to choose between compressed air and some other power to do mining work, "Utility" should always be the standard for comparison.

It is seldom that any set of conditions calls for the exclusive use of one kind of power, and it is not good engineering to make an installation the victim of any fad or prejudice. Whether it be steam, electricity, water power or compressed air, or a combination of any or all of them, let the sole and only qualification be determined on the basis of *commercial* efficiency.

CHARGING MACHINES FOR CUPOLAS*

The designers are indebted to the blast furnace operators for the idea of the charging machine. Every one is familiar with the skip hoists and the great saving effected over the old practice of using elevators and dump buggies pushed by laborers. This refinement in handling charges naturally was introduced by the blast furnace people, as their operations are continuous for months, 24 hr. a day. The elimination of laborers made tremendous economy in cost of production. The skip hoist is an end dump and is fitted with automatic features which would not be applicable to the conditions in cupola practice. There have been end dump machines used for cupolas, and the author believes such a device is in use at the Pennsylvania Car Wheel Company. The Whiting Company has adopted the side dump, claiming it to be simpler and better for continuous movement of cars. Other advantages are that there is less handling of cars and a narrower charging floor is permissible.

The construction of the Whiting pneumatic machine is illustrated in the drawings. Fig. 1 gives elevations of the machine with the car

*From a paper by G. R. Branden, read before the Pittsburgh Foundrymen's Association March 2, 1908.
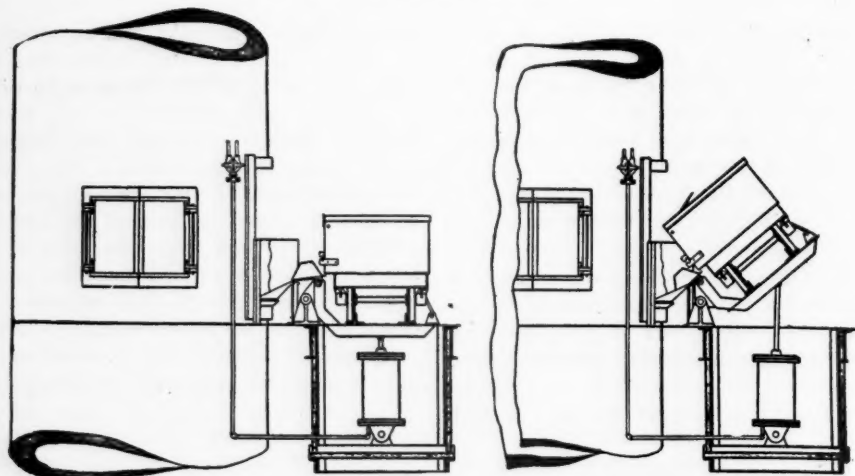
FIG. I.—CUPOLA CHARGING MACHINE WITH CAR READY TO DUMP AND IN DUMPING POSITION.

in position ready for raising and in dumping position. The machine consists of a platform hinged at a level above the charging platform on the side toward the cupola, provided with a track for the charging car in line with the stationary tracks, guard angles, as shown, and a hook for holding the car to the platform when being dumped. A dumping cylinder is supported by framing attached to the charging floor and pivoted to allow the slight swing required when the platform is tipped. The piston rod is pivoted in a bracket attached to the underside of the platform. The platform is constructed of structual shapes and all joints
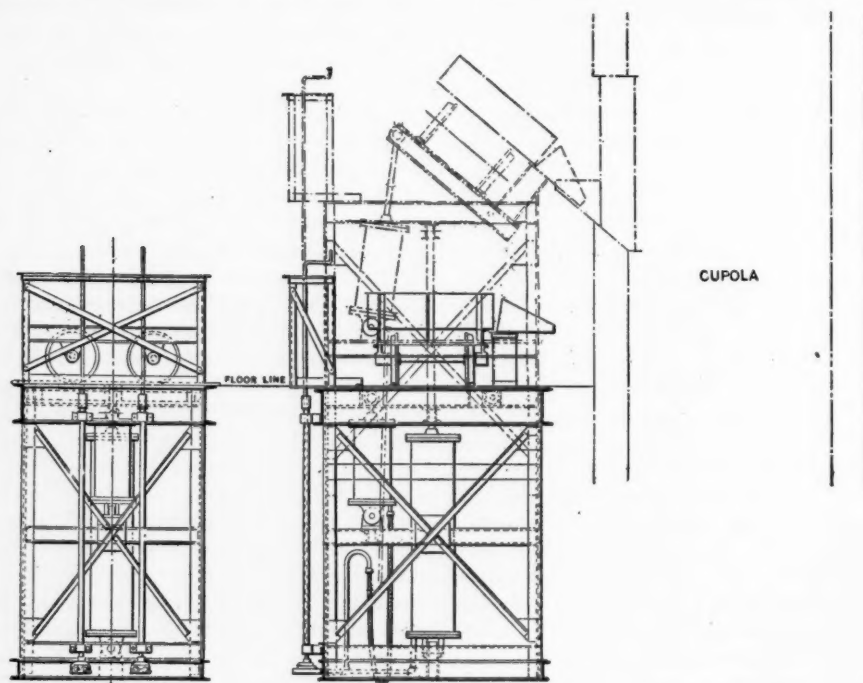

FIG. II.—FRONT AND SIDE ELEVATIONS OF A COMPOUND CUPOLA CHARGING MACHINE
ARRANGED TO ELEVATE CAR BEFORE DUMPING.

are strongly riveted; the hinge pins are of ample size and are arranged for easy removal and replacement. An apron plate is hinged to the platform and laps over an inclined chute in front of the cupola door. The controlling valve is located at any convenient point and is piped to the cylinder and connected with the air supply.

In operation, the car is run on the platform and the hook engaged with an eye attached to the car frame. Then the valve is opened to admit air into the operating cylinder, and the platform is raised to the dumping position. The iron charges are put on cars with ends about 12 in. high, but open on both sides. Coke cars have ends and sides inclosed, one side being fitted with a hinged door. By manipulation of the valve the charges may be distributed as desired. The level of the charges must be maintained 3 to 4 ft. below the level of the door sill to get the best results. Electric power may be used in place of compressed air, using a geared hoisting machine. The ordinary crane controller will give the different movements and speeds required.

A device of this character is necessarily of greatest benefit where the cupola output is large and the speed of melting relatively high. A cupola 54 in. in diameter inside of lining is about the smallest size which should be charged by machine. With a No. 9½ Whiting cupola, 90-in. shell, 72 in. inside diameter, and melting 20 tons per hour, two men with the charging machine perform the work which would otherwise require five or six men. Assuming the duration of heat to be 4 hr., the saving in labor will be 12 hr. time, at, say, 17½ cents, or $2.10 per day, which represents an annual saving of $630, or about 200 per cent., on the investment.

The charging door in the cupola for use with this machine is 9 in. above the charging floor. To obtain maximum economy of fuel the charging floor should be from 20 to 24 ft. above the bottom plate, or about 5 ft. higher than for hand charging. Other charging doors, at ordinary hight for hand charging, are located at the sides for use in emergency, and for leveling the stock charged by the machine if this should ever be necessary.

The company has devised a compound machine, shown in Fig. 2, for use in connection with low charging floors, consisting practically of an elevator of the plunger type, which lifts the car and charging machine together to the required level. The two mechanisms are controlled independently and may be operated by pneumatic power, as shown, or by electric power. The original charging doors may be left in the cupola, being shifted as necessary, and used for hand charging and leveling.

DRYING WOOD

The question was recently asked, "What do you mean by stating that a drykiln should be arranged to dry by means of a natural draft as being most economical and effective, also automatic in its operation?" To answer briefly, drying by natural draft is an arrangement using only heat and the moisture in the lumber to circulate the air or give draft to the kiln using the open-air method; or, heat, the moisture in the lumber and cold water, in the condensing method. One advantage is, over that of some of the force-draft methods, in having as applied by the sun a radiant heat within the room.

Its economy is partly in the fact that it is automatic, the movement of the air being quickened by the moisture absorbed (the air becoming lighter as moisture is absorbed in the form of gas), and as the moisture decreases (the lumber becoming dry) the air becomes less rapid in its motion, although increasing in temperature. In the force-draft method the draft, being created by force outside the kiln, plainly cannot be automatic or natural, and is only capable of regulation by constant attention of the operator.

The changing methods of drying have been brought about also by reason of the continued demand for better work from the manufacturing wood-worker. The first method—that of the fan—came undoubtedly from the observation of the effect of the wind in drying, without any understanding of physics or that Nature's method of drying the tree is to destroy it as quickly as possible. Then, to save the cost of the fan and the cost of its operation, came the chimney-draft method. This was followed by the repression, or what we term the moist-air natural-draft kiln, as being less influenced by air pressures (winds and changes of climate). Lastly, we have the condensing kiln which, not being open to air and using a strictly natural draft is, while of more perfect control, also of much better econ-

omy in its operation, and came only by reason of the demand of the manufacturer for better economy in the use of steam and more perfect drying of the product.

All methods mentioned have survived, the two first by reason of their more rapid work on softwoods, when the difference in value of low-cost steam in greater consumption is held to be balanced in the lessened cost of amount of radiation needed, but, in using exhaust steam by applying in part direct, it possibly dooms the force-draft method of drying lumber.—E. E. Perkins in *Woodworker.*

VOLUMETRIC EFFICIENCIES OF AIR COMPRESSORS

At the Royal Technical College at Dresden, Germany, W. Heileman, using the special compressor installed there, has recently made some investigations of compressor efficiences. The compressor is belt driven and has three cylinders, only two of which were used in the tests. These cylinders were: *A,* 10.2 in. diameter by 11.8 in. stroke, double-acting, with tail-rod and oscillating rotary valves; *B,* 8.65 ins. diameter, 11.8 ins. stroke, single-acting, poppet-valves. The delivery pressures were varied from 21 lbs. to 114 lbs. per sq. in. (gage), and the speeds from 52 to 108 r. p. m. The chief quantities obtained from the tests were: (1) The ratio volume of air at suction pressure to piston displacement, called volumetric ratio; (2) the ratio of air volume measured under atmospheric conditions to piston displacement, called capacity ratio; (3) the ratio of isothermal energy of delivered air to the indicated work of the compressor, called indicated efficiency.

For cylinder *A,* the volumetric ratio varied from 93.4 to 97.2 per cent., the capacity ratio from 73.0 to 91.9 per cent., and the indicated efficiency from 55.1 to 76.8 per cent., when the rotary valves were worked without pressure equalization. Substituted valves with pressure equalization gave materially lower figures, namely volumetric ratios of 92.9 to 95.1 per cent., capacity ratios 57.8 to 84.4 percent., and indicated efficiencies of 42.4 to 68.5 per cent. The indicated power in both series of tests ranged from 4 to 20 HP. Cylinder *B,* fitted with poppet-valves, gave the following results, with indicated powers of 1.6 to 7.9 HP. Volumetric ratio 90.2 to 94.5 per cent., capacity

ratio 83.2 to 94.5 per cent., indicated efficiency 63.4 to 73.1 per cent.

The results show a very variable relation between volumetric ratio and capacity ratio, which latter figure is of most practical interest. An attempt to calculate the latter from the volumetric ratio, full temperature observations being made, gave results differing from the true value by the maximum amounts of 7 per cent., 21 per cent. and 34 per cent. in the three series of tests. The amount of cooling water used in the cylinder jackets was found to have little influence on the volumetric ratio, but naturally a considerable influence on the capacity ratio, the latter being increased by increased cooling. Both the capacity ratio and the indicated efficiency decreased with increasing ratio of compression and the decreases were considerably larger in cylinder A than in the other.—*Zeitschrift des Vereins Deutcher Ingenieure.*

THE PROCTOR TUNNEL BORING MACHINE

It seems to be somewhat obligatory upon us to show this machine, at least as a mechanical curiosity and as illustrative of the daring of the modern inventor. It is an air operated machine and has been actually built, although it has as yet no actual record of performance.

The cut, which we produce from *Mining Science,* shows the construction and the principle of operation of the machine with remarkable clearness. The idea is to cut a circular tunnel out of the solid rock exactly to the required dimensions leaving the surface smooth and true. The material removed is all cut up into fine chips instead of being taken out in rough masses of portable size. There is no drilling of holes and no blasting and the machine can work and advance without interruption.

The cutting head is attached to a large hollow shaft, which in turn is mounted on a heavy "I" beam. This is supported by frames carrying large supporting wheels which bear on the floor of the bore, keeping the head in position and allowing it to progress as the breast advances. The position of the head is steadied by the use of a smaller wheel held in contact with the roof of the bore by the use of a rod and piston actuated by air pressure from below. At the rear end of the "I"
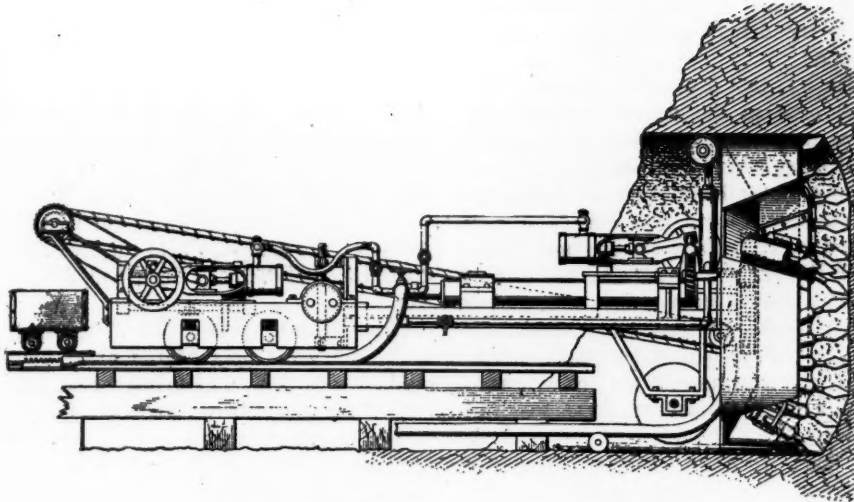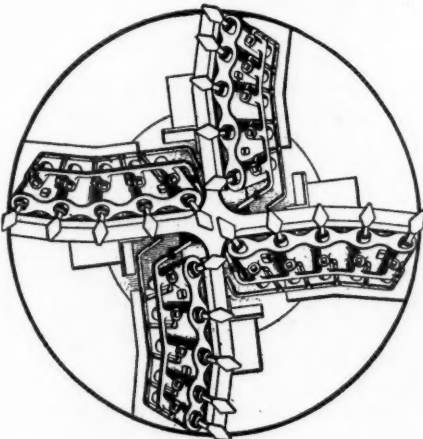
THE PROCTOR TUNNEL BORING MACHINE.

beam there is a jointed connection with the frame of an operating truck. This joint is so arranged that the position of the head can be adjusted to change the direction of advance, either laterally or vertically.

The working head rotates slowly inside of a short cylinder or shield and carries a series of scoops which take up the debris from the lower part of the shield and, carrying it up and over, delivering it to a hopper, which in

FACE OF CUTTING HEAD.

turn feeds it to the conveyor belt. This belt carries the debris back and delivers it to the car which stands on the tunnel track underneath and in the rear of the operating truck.

The cutting head is composed of four arms which of themselves are composed of a series of cylinders, each one of which operates an individual cutting tool by compressed air. They are simple in construction and act on the principle of the air hammer. The tools are so arranged as to give an oblique blow and are designed to follow as nearly as possible the natural chipping action ordinarily used in the surfacing of stone. They are made with a bit similar to the ordinary moil. The arrangement of the cylinders in the arms of the cutting head is such as to "stagger" the circles of cutting so that no two bits will follow the same path. They are spread somewhat in a fan shape, so as to reach all points of the breast from the center to the extreme edge of the bore which is a trifle larger than the shield. The operating truck runs on a special track and is equipped with a pinion which engages in a rack attached to the trackbed. This progresses the truck, and with it the cutting head and is readily regulated as to the speed of the advance by the use of a disk regulator. By this same means the action is reversed and the entire machine is backed away when required.

A REPORTER GOES THROUGH THE TUNNEL UNDER PRESSURE

When the opportunity came of going down into the Pennsylvania East River tunnel and of being the first man outside the working force to gain Long Island City by this unusual way, soon to be daily followed by millions, I confess I knew almost as little of the world-wonder which has been accomplished in our midst as any other New Yorker. We

are convinced that all live in no "mean city," but as to the details we are all, I think, a little vague.

My idea was that I would hop down a ladder, and, once in the tunnel, mud-lark my way along until out of the muck and mist the glories of Long Island City, which I had never seen plainly, would burst upon me. Should I wear a mackintosh or a rain coat or rubbers were the questions which agitated me.

Once I reached the caisson at the foot of Thirty-third street, from which the tunnels begin their mucky way, my plans were made for me. A doctor applied an instrument to my heart and guaranteed me to withstand high and hot air pressure for the space of half an hour.

"Now don't let those 'sandhogs' keep you down there all day," he said, in kindly warning. "They will want to show you everything. Cut it out and come back in half an hour."

In a trice I was dressed like all the sandhogs and looked, I felt, very much like a stage version of Jules Verne's Captain Nemo about to prepare for twenty thousand leagues under the sea. We were soon aboard an elevator in the caisson, and sinking with many rough jolts into the bottom of an apparently endless shaft. At last we came to our moorings with a rough bump, and I steppd out; to all appearances I had made a mistake in the stage drop and would have to begin all over again. I seemed to have fallen into the lower stories of the Hotel Belmont or some other of the modern buildings which extend as far toward the center of the earth as they do above the conservative steeples of our fathers.

We were in a subaquious or subterranean— I am not quite sure which—palace of tiled brick, lighted by electricity to twin the brightness of the most garish day. I was turning to look for the subway station, the barber's shop, the broker's office, perhaps the bar, for clearly they all had their place and position in this palace of modern life, when suddenly, drawn by magic it seemed—an endless cable I afterward learned—a whole convoy of muck carts came into view, loaded down with the débris of the East River's last resistance to the power of compressed air and hydraulic jacks.

We followed the tunnel in an atmosphere that was sweeter and cleaner than any cellar I had ever entered, and pushed along for a

hundred yards or so, until our way was blocked by a huge boiler, heavily riveted and clamped, as though contrived to keep within its belly some demon destructive of man and his works. A little mantrap was opened, and we crept into this metallic coffin, the trap was closed behind us, a man opened a lever, and in a few seconds our coffin was filled with a dense mist. He was only three feet away, but I could only dimly see the man who held the lever, and the man who watched the air clock had disappeared from view.

"Not so fast, not so fast," suggested Mr. Moir, the great boss of the great hundred-million-dollar job. The man reversed the lever, and the atmosphere cleared as if by magic.

"I suppose you never knew why fogs occur," said my amiable mentor. "It is the contact of different atmospheric pressures. We must sit here until the atmosphere is equalized. When we entered it was normal. When we make our exit it will exercise a pressure of fifteen pounds to every square inch of our bodies." Slowly, and with infinite care, the high-pressure atmosphere was admitted. Now and again there would be a rush of fog, instantly banished by a gesture from the all-controlling boss of the job.

"Ain't it awful," murmured one of the "sandhogs," probably impatient at the careful slowness of my initiation to strange atmospheres. "If he can't blow air out through his ears he'll have to go back."

Now, the pressure was quite considerable. I was made to stand up. My mouth was as dry as the sands of the Sahara, I was ordered to swallow continually, then through my ear drums ran a sharp pain. "I will hold your nose tight, pull it even if you don't mind, and then you'll blow." I blew, and out of my ears came the winds, or they seemed to, as from the cave of Boreas.

"Jimmy" Sullivan and Ryan, the premier "sandhogs," were delighted.

"You done it and you done it beautifully," they said. It was pleasant to think that while I contributed nothing to the great work, and in nowise deserved the piece of the cutting shield with which they afterward honored me, the flexibility of my ear drums and the openness of my air tubes had prevented me from retarding the great work.

Now the atmosphere was equalized, both clocks [pressure gages] agreed, the door of our iron coffin at the opposite end to where

we had entered was opened and we stepped out into the new atmosphere. In this zone the tunnel, the last of the four, was nearly completed, even to the finishing polish and furbelows which tunnels receive as well as gowns—the concrete men were on their job, and only the passing of the mud carts told that far ahead men were still at work in an atmosphere of mystery and danger. We staggered along, or seemed to, and every one I saw seemed to walk with a sailor's roll. Soon we were seated in another, and the last air lock, having our systems toned up to an air pressure of 31 pounds to the square inch of body surface.

"Jimmy" Sullivan had my nose in a vice-like grip, and I blew out the air through my ears. It was nice to have him say again I "done it beautiful," but suddenly the master of the job shattered all my illusions as to my new accomplishment.

"You think you are blowing air out through your ears; it feels that way, and I could talk till doomsday without convincing the "sandhogs" that they are not. The fact of the matter is you are admitting the air of the new atmosphere into your head, and if you didn't it would burst your ear drums; you see the air pressure has to be equally adjusted."

"What would happen if while we are still half way suspended, as it were, between atmospheres the door of the air lock should come open?" I inquired.

"We would burst," said the master boss. "The air clash would be tremendous—we would be torn to pieces."

"No," said Ryan, who loves to live at the head of the cutting and has to be forced home at nights. "No one knows whether we would be torn to pieces, for there are never any pieces left. Once I have heard big Bill tell about a job he was mixed up with, and how ten men were sitting in the air lock when the door burst, and you know them ten men altogether didn't make a grease spot.

"Blow hard, blow hard," said "Jimmy" Sullivan. The pain in the ear drums passed with the rush of air, and we passed out into the thirty-one-pound-pressure atmosphere.

You can do anything down there that you can do in our normal atmosphere but whistle —that faculty is lost. Out of the thousands and tens of thousands of men who have worked in the tunnel at the front of the heading only one man could whistle, and he died suddenly one day whistling "Down on the Suwanee River," and the doctors said he had the lungs of a bull rather than those of a man.

We staggered along now in the muck and the mist. Each man was doing his allotted task calmly and gravely, but all men knew that death was not far away if only by the escape devices. We climbed into the refuge fifty yards behind the heading, and Mr. Moir explained convincingly how any man who reached here was safe from inundation, "blowouts," and all the other dangers which beset the "sandhog." "He would become encysted as it were, in the air cell, and nothing could reach him. We have only lost two men since our safety screen was erected. One poor fellow was bringing his shovel with him. He got it jammed in the door and the waters overtook them."

Stumbling over timbers, air pipes, electric wires, clay bags to blow into leaks we staggered along to the shield and the cutting edge. The shield is a wonderful machine, but you will never understand it from my description, for a realizing sense of the steel monster you will have to see it yourself. Around the shield which fills the whole circumference of the tunnel are arranged twenty-seven hydraulic jacks which force the hardened cutting edges through every kind of geological formation, mining and dynamite assisting when most stubborn rock is encountered.

In the murk and the mist and the drenching fog already we could see the glint of the shield that had traveled from Long Island City, and we could see that the two powerful engines were only eighteen inches apart. The jacks were started, the shields quivered and shook, they moved forward, like caterpillars resting on their tails, and soon they touched all around the circumference, but for an impertinent rock lodged in one corner. "Jimmy" Sullivan was for blowing the thing to smithereens, but Moir said:

"No bulldozing, boys, now, least of all when we have got the East River, backed by the Atlantic Ocean, just where we want 'em." Quietly he plotted the destruction of the rock, and together we climbed into the Long Island shield, while both gangs cheered the completion of the work and the man who had been

with them and guided them from start to fin-
ish.

"Now you have an idea of the conditions
under which the battle has been fought," ex-
plained the master builder. "All we have had
to do really was to keep cool and not get
excited. I think we have done that for four
years, and the rest was easy. We have kept
the water out of our tunnel by compressed
air, and we have used the water to do our
digging and our cutting for us. You have got
to keep this air pressure nicely adjusted to the
water pressure from the river or you will have
blowouts. One half pound of air, speaking
roughly, holds about two feet of water, so
there's the problem. Watch your water pres-
sure and then meet it with its conqueror—
air.

"Generally we have our air compressors
making 70 revolutions the minute, but in times
of great emergency we have put it up to 240
revolutions, which produced 70 pounds of pres-
sure to the square inch, and then the water
always backed out gracefully. The problem is
to keep the water out without blowing off the
roof of the heading, and I tell the heading
bosses 'Don't be afraid of working in wet
feet. Let the water ooze in at the bottom; its
better that than making a hole for the whole
river to pour in at the top.'"

As we turned to go, "Jimmy" Sullivan was
getting to work with his fearful pet, which is
known in science, but not to "Jimmy," as an
hydraulic erector. It looked like a useless mass
of battered iron, but "Jimmy" touched some
valves and pressed some buttons, and it began
to move around with the grace of a butter-
fly. "Jimmy" watching and guiding it snooped
along the floor of the cutting, thrust out a
link into which a "sandhog" thrust a staple,
and then, as though it were lifting a feather, it
carried the last segment of the last iron ring,
weighing a ton, and dropped it into place—
practically the tunnel was finished.

When we reached the elevators it was dark
outside, the day was gone, and the doctor was
apprehensive that I should soon be on his
hands with the "bends." All the walking
bosses, where we had our coffee. were a lit-
tle sad, for undeniably the great job is finished
and the glorious day of the "sandhogs" is over.
—Stephen Bonsal in *New York Times*.

THE BOSS OF THE EAST RIVER TUNNELS

Over the great submarine construction which
would be regarded as a wonder of the world
if in this progressive age and generation we
had time for admiring and congratulatory
pauses, E. W. Moir, vice-president of the Pear-
son Construction Company, has presided day
and night for four years. The other men have
worked in eight-hour shifts, with the pleasing
interlude of pay Sunday every other week, but
he has worked for four years without inter-
mission. His belongings have lived in a spa-
cious apartment near the top of one of the new
sky-scraping hotels, and when he goes to bed,
which is seldom, according to the sand hogs,
Mr. Moir has a telescope glued to his never-
closed eye. Certain it is that from his eerie
den you can see the air bubbles in the river
proceeding from the tunnel, and he has always
turned up on the job before the telephonic
message of a "blowout" or some other of the
hundred and one obstacles which have beset
the undertaking could reach him.

Mr. Moir, the right-hand man of Sir Weet-
man Pearson, who has so many hundred-mil-
lion-dollar jobs going on in different parts of
the globe that he only comes to New York
once a year, is the most eminent practitioner
in compressed air that the world has ever seen,
and he is yet on the sunny side of 45. The
only flaw in his record is that he was born
on the west coast of Scotland, but for him
America has spelled opportunity, as it has in-
deed for all the men of the twenty-two na-
tionalities who have worked under him on the
great job.

He talks about compressed air as Sardou or
Clyde Fitch talk of the stage, with love and
respect, but without familiarity. "Com-
pressed air is like a doctor," he says. "Nev-
er call him in unless you have to. If you have
to, why that is all right." Moir likes to talk
about Lord Dundonald, who was an Admiral
in all the navies of the fighting world before
the British Admirality would give him his
chance at home, as the first man who suggested
the use of compressed air in submarine tun-
neling, and he has great praise for Mr. Great-
head and De Witt Clinton Haskins, the Amer-
ican, who began the luckless brick tunnel under
the Hudson in 1890, with Moir at his side,
but in the annals of the Royal Society of Lon-

don, before which august body Mr. Moir will shortly describe the East River achievement, you will find him constantly referred to as the builder of the Blackwall tunnel and the pioneer of compressed air work.

He has had his ups and downs like all men of achievement, and the reward for his, in view of the primitive tools at his disposal, almost incredible work, under the Hudson in the nineties was a mechanic's lien on a hole in the ground two thousand feet long, but in this failure, which was a failure only in the sense that timorous capital was not forthcoming to complete the undertaking, he acquired the knowledge and trained the men, both of which were needed to tunnel the Thames in London and the East River in New York.

The men who have followed Mr. Moir from the North River to the Thames and then from the Firth o' Forth Bridge back to the East River tunnels for the Pennsylvania system, follow him not only because he is always involved in big things and they like to be also, but because he does his best by them. The only explanation why a man should want to work in the North River tunnel the way the work was done in 1890 was because the man in question had a mania for risking his life. To-day he has a fighting chance of doing his work and moving on to another attractive job.

The pressure of compressed air at 30 to 40 pounds the average at the tunnel's heading is, of course, a danger not to be played with. In the Pennsylvania tunnels the greatest care was taken in the air locks, and coming from their work, which is the crucial time, the men were made to stew in the air chambers while the atmospheres were being slowly equalized. And still men got the "bends." Sometimes because they were physically prone to having them, but more often because, in a hurry to take their wives or sweethearts to Coney Island, they contrived to shorten their regulation stay in the transition air chambers.

To save the men from the consequences of their heedlessness Mr. Moir built another air chamber above ground, at the head of the shaft, which is manned by doctors day and night. If the sand hog is attacked with his fearful illness at the show, if an intrusive air bubble stops his circulation and menaces his life, he hails a cab or an ambulance and shouts "to the recompressor," and in that knowing east side of the city every one understands.

He is placed in the iron chamber, and the atmosphere in which he has last worked is reproduced; then gradually, very gradually, the pressure is withdrawn, very slowly the atmosphere of the recompressor approaches that of the outside, and the air bubble which threatened the life of a valuable man exudes harmlessly.

This merciful invention and generous application of it has saved scores, and, indeed, hundreds of lives in the Pennsylvania tunnels, and the grateful "sandhogs," remembering their fellow-workers and their benefactor, have had one of these air chambers, which has been the salvation of so many of them, modeled in gold and presented to Mr. Moir. He likes it because it shows the way his manly men like a manly boss, but what pleases him most about the souvenir, perhaps, being a practical man and not a sentimentalist, is that the model is a true one. The crafty sand hogs saw to that, and now the great boss can compress air with a little trinket which hangs from his watch chain wherever he goes.

THE OXY-ACETYLENE BURNER CUTS DOWN A BRIDGE

The oxy-acetylene burner used for cutting steel plates is essentially like that used for welding, except that it has an additional oxygen supply pipe. The principle is to first heat the steel to a very high temperature with the oxy-acetylene flame and then by directing a stream of pure oxygen on the hot plate to start the independent burning of the metal itself—autogenous burning. The method is simple and easy and the cut is said to be as sharp as if made with a saw. It is in actual commercial use in Europe. A transatlantic steamer had run in night time against an iron bridge which crosses the channel between the Bassin d'Eure and the Bassin Bellot in France. The bridge, which had a length of 50 meters, (164 feet) a breadth of 7 meters and a weight of 250 tons, was thereby entirely deformed and distorted so that no ships could pass the channel. Since several steamers wanted to leave the next day, it was soon found that it would be necessary to take the bridge down. This was tried with sawing, but it was found that this would take at least a week. Then the oxy-acetylene method was applied and the job was completely finished within 20 hours.

CORLISS VALVES ON AIR COMPRESSORS

SIMPLE DIRECTIONS FOR SETTING THEM, WITH
DIAGRAMS ILLUSTRATING THE TWO PRIN-
CIPAL FORMS OF CORLISS AIR VALVE
DRIVE, PLAIN AND SWING PLATE.
BY H. V. CONRAD.

Theoretically the Corliss inlet valve of an air-compressing cylinder should open the port instantly at the beginning of the stroke of the air-cylinder piston, and also close instantly at the end of the stroke, present-ing the widest opening of the port at mid-stroke when the piston is traveling at its greatest speed. It is impracticable, how-ever, to build such cylinders without end clearance, made up of the clearance between the piston and cylinder-head, plus that of the air ports under the valves, therefore, the percentage of this clearance determines the point at which the inlet valve should open.

The compressed air contained in the clearance space at the end of the stroke should be allowed to re-expand to the in-take pressure as the piston recedes, before the inlet port is opened to admit new air. This takes place automatically, when spring poppet-inlet valves are used, which do not open until the pressure in the cylinder is drawn down below the outside pressure, but the Corliss valve having a fixed travel must be adjusted to meet this condition.

THE CLEARANCE.

Corliss inlet valves are most frequently found in compound air cylinders (also those for low air pressure), where two and one-half or three total compressions occur in each cylinder, and we will assume for il-lustration the compound air cylinders for 100 pounds terminal air pressure. In this case, with the cylinders properly proportion-ed, there will be about 2.8 compres-sion in each cylinder, or 26 pounds gage in the low-pressure cylinder. Assume that the end clearance is equal to $1\frac{1}{2}$ per cent. of stroke filled with air at 26 pounds gage; to re-expand this air to atmosphere, or the intake pressure, the volume must be $1.5 \times 2.8 = 4.2$ per cent. of stroke, from which deduct the original clearancee of $1\frac{1}{2}$ per cent., leaving 2.7 per cent. of the stroke that the piston must travel before the valve opens; see Fig. 1.

If the data are not at hand, nor procurable, for making the above calculation for any par-ticular case, the valve setting must be adjusted from indicator diagrams taken from the first approximate setting. The accompanying dia-grams represent two forms of valve drive; as the straight or plain drive wherein the valves rotate equidistant either side of a center line
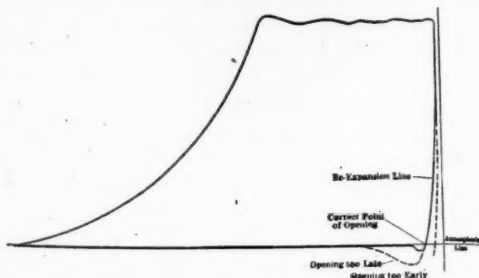

FIG. 1.

that corresponds with the center of the eccen-tric travel, and the swing-plate drive where the valves rotate through a greater arc during the open period than during the closed period of their travel.

THE PLAIN DRIVE

Referring to Fig. 2, which is a plain drive, the crank-end valve will open the port during the stroke from B to C and will close it from C through A to B. The head-end valve will open the port during the stroke from D to A and close it from A through B to D.

Having determined by actual calculation of the end clearance the length of travel the pis-ton should make before the valve should open, which, say, is equivalent to the crank-pin trav-el from A to B, determined the midpoint be-tween A and B, that is, at X. Proceed to set the crank-end valve, first by placing the crank-pin at X and place the valve-arm in an exact vertical position. M, which should place the valve on more or less lap. Then adjust the length of the eccentric rod to suit these posi-tions.

Next rotate the crank pin to B, which ro-tates the eccentric to O, and the valve arm to O^2, which should bring the valve line-and-line ready to open; if not, alter the length of the eccentric rod and adjust the valve so that it will come line-and-line. Then turn the crank pin to the center C, which rotates the eccentric to P, and the valve arm to P^2 at which point

FIG. H

Position of Valve when
Crank and Eccentric are at D and S (Opening)
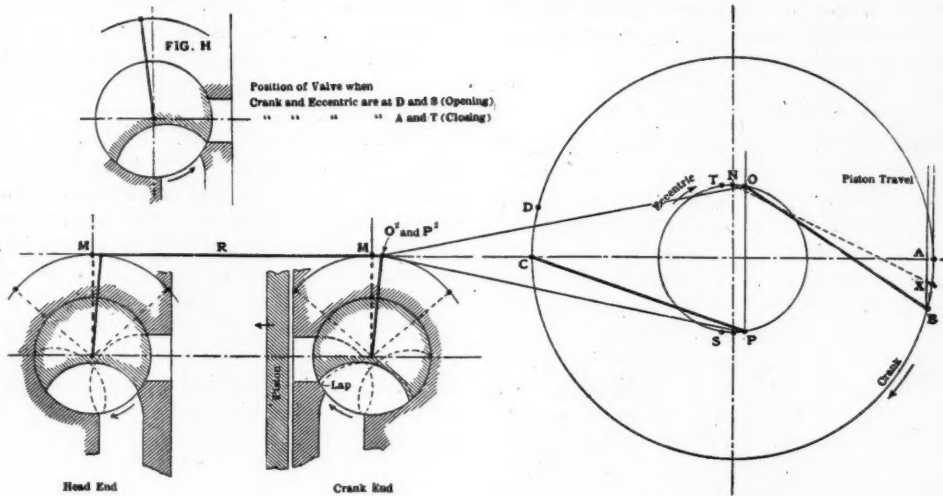"   "   "   "   A and T (Closing)

FIG. II.

the valve should be found line-and-line for closing. The valve at the head end of the cylinder is next adjusted by placing the crank pin at D, opposite B, and lengthening or shortening the valve rod R so that the valve stands line-and-line for opening the port, see Fig. H. Then turn the crank pin over to the center A, when the valve should be found line-and-line for closing.

If indicator diagrams taken under speed and pressure conditions show that the valve opens too late or too early at the beginning of the intake stroke, see Fig. I, it means that in case of too late an opening the valve has too much lap and that position B, and consequently X, should be nearer A, which in readjusting the eccentric for this new position throws it further back. If the valve opens too early, not having enough lap, position B, and consequently X, should be farther ahead from A, which throws the eccentric farther ahead.

In this form of drive the eccentric follows
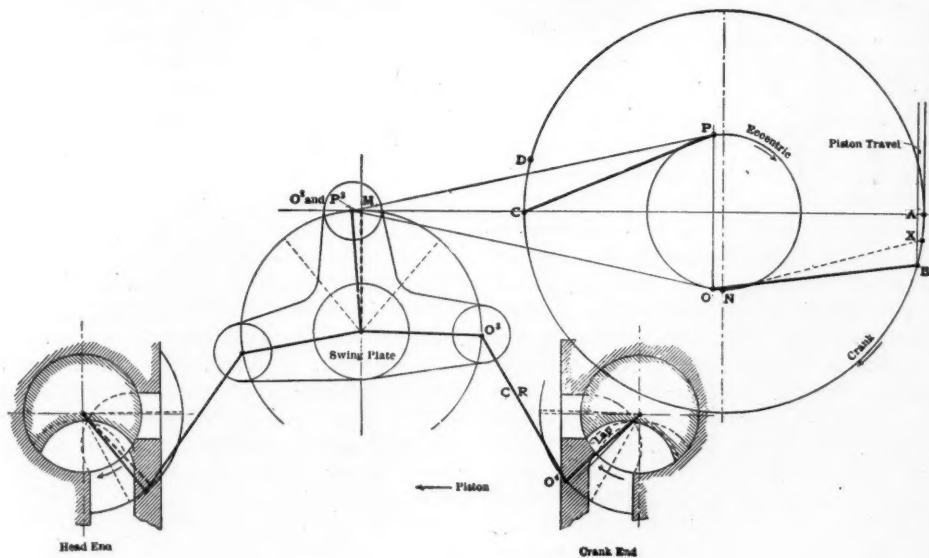
FIG III.

the crank, provided the motion is not reversed by intermediate rockers; if so reversed the eccentric leads the crank.

With the swing-plate drive the valves should open and close during the same periods of stroke as in the previous case, and the letters of the diagrams correspond. Suppose the valve of the crank end is to be set first, place the crank pin at point X, as determined in the case of Fig. 2, and place the swing-plate on the vertical center line M, Fig. 3. Then place the eccentric in the lower vertical position N, or 90 degrees ahead of the crank pin center A, and adjust the length of the eccentric rod to suit these positions. Next move the crank pin to the position B, which rotates the eccentric to O and the swing-plate to O^2. The crank end valve should be placed line-and-line for opening the port, at O^4, by adjusting the length of the valve rod CR. Then rotate the crank pin

line-and-line for closing. If indicator diagrams show that the valves open too late or too early, the correct point of opening should be arrived at as in the case of the straight drive.

In the swing-plate drive illustrated, the eccentric leads the crank unless reversed by intermediate rockers in the valve gear. The diagrams are not drawn to scale, nor the details in exact relative positions to each other, but they illustrate the two principal forms of Corliss air valve drive without taking into account the many various arrangements of detail to be found in use.

In compound compression the setting of the inlet valves of the high pressure cylinder is carried out on the foregoing basis.
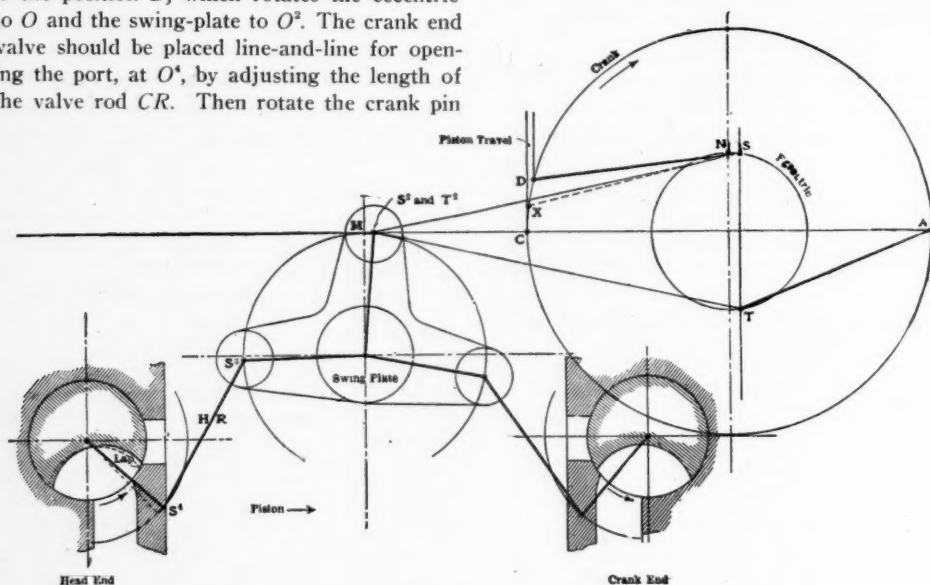

FIG. IV.

to the centre C, which rotates the eccentric to P and brings the swing-plate back to P^2, where the valve should be line-and-line for closing.

The valve of the head end of the cylinder should next be adjusted. Place the crank pin at position D, Fig. 4, diagonally opposite B. which rotates the eccentric to T and the swing-plate to S^2. Then place the valve in the position S^4, line-and-line for opening, by adjusting the length of the valve rod $H R$. Next rotate the crank pin to the end of the stroke A, which rotates the eccentric to I and the swing-plate to T^2, at which point the valve should be

The Cassier Magazine Company announces the removal of its New York offices from No. 3 West 29th St., to No. 12 West 31st St., to which latter address all communications should hereafter be sent. The new home of Cassier's Magazine is in the office building just erected on the site of the former house of the American Society of Mechanical Engineers, a location especially convenient of access from the new railroad terminals and easily reached by the various systems of local transport.

COMPARISON OF HAND AND MA-
CHINE EFFICINCIES

OLD AND NEW METHODS IN PANAMA CANAL
WORK.

D. W. Bolich, Division Engineer, Culebra
Division, Canal Zone, gives in *The Canal
Record* an interesting statement of certain
work done and of the comparative cost, es-
pecially in manual labor, under the French
engineers years ago and under the engineers
at present in charge of the work. The com-
parisons do not involve nationality, but rath-
er the old and the new or hand and machine
methods. The notes as to present work are
based upon the work accomplished in Cule-
bra Cut during the final month of the last dry
season.

STEAM SHOVELS.

There are sixty steam shovels some of 75
tons and some of 95 tons, the 70 ton shovels
having 2 1-2 and 3 1-2 cubic yard buckets and
the 95-ton 5 cubic yards. We have had shov-
els that loaded as much as 2,175 cubic yards
of mixed rock and dirt (about half and half)
in one day of eight hours. Of the 44 shov-
els which we averaged daily at work during
the month of March (1907), each averaged
18,600 cubic yards for the month, this repre-
senting for a day for each shovel 744 cubic
yards. Say that a good man would load 6
cubic yards in eight hours, this would equal
the work done by 124 men, and the work
done by 44 shovels, in loading only, would
represented the work of 5,456 laborers, as
against 298 laborers used as pit men in mov-
ing up the shovel and clearing track and fire-
men, the two white men on each shovel (en-
gineer and craneman) about equaling the
number of white foremen necessarily to han-
dle 5,457 laborers.

BLASTING.

Another point that should be remembered
in using the steam shovel as a means of ex-
cavating the cut, is the question of drilling
and blasting the ground into such sizes or
weights, as that men could load same on cars.
A man will generally handle a rock weighing
150 to 200 pounds, or 1 1-2 to 2 cubic feet;
a steam shovel will handle rock weighing
21,000 pounds, or 189 cubic feet (taking
weight of rock at only 3,000 pounds to the
cubic yard, which is very low).

Comparing with men loading, the fact that
we would have to do fully twice, if not three
times as much drilling as for shovels must
be considered, and also that while we can,
for a steam shovel, blast a cubic yard of
material with one-third pound of explosives,
for men, we would use a pound of explosive
for a cubic yard of material loaded. There-
fore, on our drilling and blasting, instead of
700 to 800 men, it would take 2,100 to 2,400
men, and instead of using, as in the month of
March, 260,000 pounds of explosives for an
output of 815,270 cubic yards, it would have
been necessary to use 780,000 pounds, or
more, of explosives to do this part of the
excavating by hand.

SPREADERS AND TRACKTHROWERS.

On the dump ground as to tracks: These
are laid by hand and do not involve the
question of machinery. After the track is
once laid, it becomes necessary to keep
throwing it out to the edge of the dump in
order to distribute more material. In throw-
ing this track, we use a track throwing ma-
chine. This machine will throw 5,400 lineal
feet (or 120 feet over a mile) of track, 9 feet
in eight hours, and represents the work of
500 to 600 men in the same length of time.
This machine is handled by three white
men and six laborers, and as 5,400 feet of
track thrown each day 9 feet on an 18-foot
height of dump would take care of the daily
output at this time, this machine would
show, therefore, a saving in the number of
laborers of from 500 to 600 men throwing by
hand. The nine men operating this machine
are about equal in number to the foremen
that would be required to direct a gang of
500 to 600 men.

In unloading material from cars with plows
and unloaders, a material gain is made in the
less number of laborers needed to take care
of the output. The best record that has been
made here by a single unloader has been 16
trains in eight hours, or 5,000 cubic yards.
This shows that 7 unloaders and plows would
take care of our daily output as to the
month of March, and would mean that 28
white men and 42 laborers and firemen with
the machines, could unload 32,000 cubic
yards a day. Estimating that a man would
unload 12 cubic yards a day of eight hours
by hand (as against 6 cubic yards loading) it

would mean that by old methods, or unloading by hand, it would take 2,660 laborers with necessary white foremen (say 100), as against machines with 28 white men and 43 laborers and foremen. This has actually been accomplished by one machine. But, even assuming that 20 machines were used, the comparison would show that the machines with 120 laborers would accomplish as much in unloading as 2,660 laborers by hand, the white men on the machines being about equal in number to the white foremen handling the laborers.

After material has been plowed off the cars it is then pushed away from the track by spreaders, which throw the material out from the track on which cars have been plowed, from 9 to 12 feet, and cut down the new material to the bottom of the ties of the track on which the spreader is working.

This machine, in a way, does not save handling all the material by hand, as, naturally, with track thrown out to edge of dumps most of the material runs down side or slope of dump, but it does save in the cost by not making it necessary to throw the track to the edge of the dump every cubic yard per foot of the length of the dump and thereby stopping the use of the dump every hour or so; else the material plowed off cars would have to be handled by hand.

This machine really expedites the progress of the work, but to accomplish this by hand would involve, without doubt, the use of 3,000 laborers as against eight machines, 16 white men and 24 laborers and firemen.

AS TO HANDLING OF MATERIAL.

Hauling the material from the shovels, or the starting point of the output, to the disposal, or the dumping of same, brings in the transportation or train service, and the modern engine and car as compared with the engine and car of 25 years ago.

The engines as used by the French companies, and which have been rebuilt by us (i. e., the standard type used by them), will haul 10 or 12 of the old French dump cars, which hold (as we estimate in our reports) 4 cubic yards, or would represent a train carrying 48 cubic yards of material.

Our engines haul 20 Western dump cars of 12 cubic yards each or 240 cubic yards of material per train, or 17 flat cars of 18 cubic yards each, or 306 cubic yards material; or

to haul our present output of 32,000 cubic yards daily, it would take 666 French trains, as against 133 trains of Western dumps, or 104 trains of flat cars of our American equipment.

NEW AND OLD METHODS COMPARED.

As a comparison of methods used by the French (which, of course, were the methods in vogue twenty-five years ago, on construction work, even in the United States, or you could say hand work only), with the modern machinery and 7,000 men, superintendents, foremen, timekeepers, laborers, etc., all told, on the Culebra Cut, we are getting out and disposing of, as to month of March, 815,270 cubic yards as against 282,528 cubic yards by the French at the height of their operation when they took that amount out of Culebra. Cut in one month with 16,000 to 18,000 (record not quite clear) laborers alone, not including their superintendents, foremen, etc., although probably of this number of laborers 50 per cent. was the efficient working force, or 9,000 laborers. The results per month would be per laborer 32 cubic yards each, under the French as the output of every man connected with the Culebra Cut of 116 cubic yards each per month under the Americans.
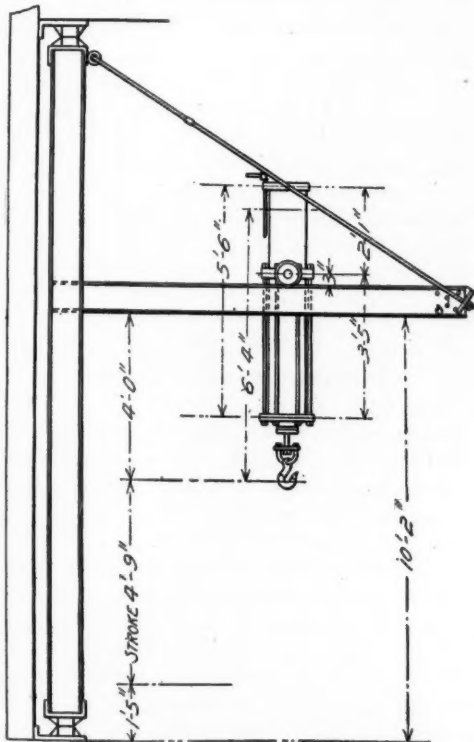
It should be considered here that our figures are from actual results and not from what the working plant should be. It is not considered at this time that the steam shovels are working more than 60 per cent. of the time they should, on account of all the rolling stock necessary to keep the shovels goceived, though ordered.

To get the full output, would not involve any material increase in the number of laborers now working, as it is considered that the maximum number of laborers required to get the daily output to the amount necessary to complete the Culebra Cut in five years, has very nearly been obtained.

Grass along the track and right of way of the Northern Texas Traction Company for thirty-five miles between Fort Worth and Dallas is now removed by an oil burner mounted on a flat car run slowly over the track. Crude oil is used as fuel. The outfit consists of a motor-driven air compressor, two air reservoirs, three oil reservoirs, and four burners, together with the necessary valves and fittings.

AIR HOIST JIB CRANES

The dimensional cuts on this page, adapted from the Electric Railway Review, give all the essential particulars of a series of handy air hoist jib cranes in service in the Emeryville (Cal.) shops of the Key Route and the Oakland Traction Company. These cranes are installed at the ends of pits in the shops and also near the large machine tools. Each crane supported at the top and bottom by trunnions comprises a vertical post of structural shapes which give easy radical movement. The horizontal arm is made of two light I beams between which the cylinder travels supported by a two wheel carriage. The cylinders are 9-in. diameter and the pistons have a travel of 5 ft., the usual shop pressure of 75 lbs. giving a

the hoist automatically at any point, and when at its lowest position it stops the piston before it strikes the top head.

THE AIR HOIST.

JIB CRANE WITH AIR HOIST.

lift of 4,500 lbs. The lift and descent is entirely controlled by a three-way cock located near the lower end of the cylinder, hand chains from the cross handle hanging down within easy reach of the operator. A set collar on the piston rod may be located to stop
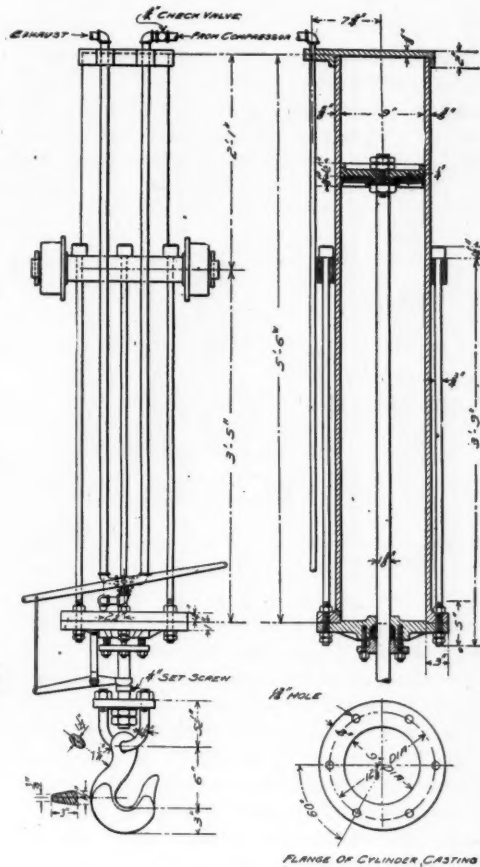
An English manufacturer of carbon brushes has brought out a brush holder for turbogenerators in which compressed air is used for maintaining the brush pressure. The brush is attached to a brass piston which moves in a cylinder, the pressure upon the piston being applied through a rubber cap or bag which surrounds the end of the air supply pipe. The pressure, which is about 3 lb. per sq. in., is secured initially by a foot pump and is afterwards maintained by a weighted cylinder. Satisfactory results are said to have been secured on small turbo-generators running up to 2,500 to 3,500 r.p.m.

A HOME-MADE COMPRESSOR AND HAMMER

The sketch herewith tells us quite clearly about a home-made portable air compressor and a pneumatic jack or hammer, described by a correspondent in a recent issue of the *American Machinist*. The compressor is made from a little two cycle gas engine, in which capacity it seems to have been not much of a success. It would run like sixty until it got hot, and then it would backfire and stop. The
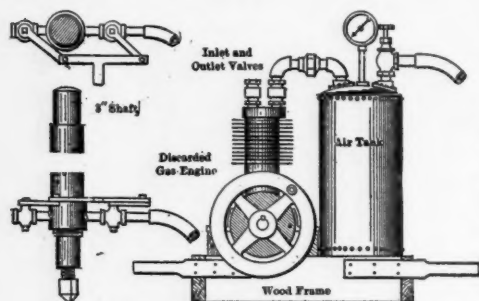
cylinder is a piece of 3 inch pipe, one end screwed into the crank case and the other closed with a pipe cap. The radiating air coating blades are of sheet steel bored and shrunk on. As an air compressor it is of course single acting with inlet and discharge valves both in the top head or cap. In the shop the flywheel may be belted to any convenient pulley on the line shaft or elsewhere. When the rig is carried where there is no power available a handle is screwed into the wheel and it is cranked by hand. The receiver is a 10 gallon galvanized iron tank fastened onto a 2x8 inch beam close to the compressor. The air is conveyed from the tank to the hammer by a piece of garden hose.

The cylinder of the hammer is a piece of common iron pipe bored smooth. If brass pipe had been used it would not have required boring and would probably been cheaper and better. The cylinder in this case was 3 by 15 inch and the plunger a solid piece of 3 inch shafting 18 inches long with a cup leather packing on the end. The hammer of course is not automatic but strikes a blow every time the pressure cock is opened, this movement closing the discharge cock, and *vice versa*.

We are assured that this simple arrangement is not to be dispised. It has been used

for driving back crown sheets, as a holding-on bar and for driving stay bolts. It could be used to good advantage even in an up-to-date shop for driving in close places. Good sized bulges in small fire boxes have been driven back by it. This was done without heating, as the fireboxes were only large enough for a small man with the hammer.

FLORISTS USE COMPRESSED AIR

At the greenhouses of Poehlman Brothers Company, near Chicago, said to be the best equipped if not also the largest in America, with 22 houses of American Beauty roses ranging from 185 to 400 feet in length, a novel method of cleaning the rose benches has been put into practice. Compressed air is piped along the center walk and connections are made with the benches. An operator with hose and nozzle can start at one end of a run and blow all the dead leaves from the stock and loose straw from the manure, collecting all at the end of the run by a curtain of canvas stretched at the point beyond which it is not desired to go. A very little time is required to do the work, and the appearance of the houses is wonderfully improved. At this estableshment the air lift also is in operation at various points.

CHICAGO WATER LOOP

The following was given to the daily press of the country on the *First* of April. Whether the date had anything to do with it we are not informed. A twelve-million dollar water loop to encircle the business part of Chicago, is proposed by Frederic A. Delano of the Harbor Commission. The loop, if constructed, is to consist of a canal 300 feet wide, extending from Lake Michigan to the south fork of the Chicago River, at about Twenty-sixth street. This would form a complete water loop wide enough, and to be made deep enough, to accommodate the largest ships of commerce. Mr. Delano points out that vessels could enter the busiest centre of the city at the north gateway, load or unload, and proceed out to the lake again by the southern door, which is to be by an extension of the artificial waterway from the south fork eastward through Twenty-second or Twenty-sixth street to the lake.

CONTENTS

DISTRIBUTING THE COST OF DISTRIBUTED BENEFITS

The original New York Subway, since the recent opening of the line to Atlantic Avenue, Brooklyn, may now be looked upon as a completed system of popular transport, and COMPRESSED AIR, representing the principal and most responsible physical agent in its construction, cannot well avoid some notice of this important consummation. In the course of time —and not a long time—there will naturally be additional branches from and extensions of the present lines, and close connections with other lines inevitably to be built; but as it is now the Subway must be considered a very complete system, with some of the features of it highly satisfactory, but with one special cause for dissatisfaction and regret. The Subway connects the three principal boroughs of Greater New York, bringing them practically much closer together and in more intimate and sympathetic touch. Its two termini, or, more correctly, three, are in the most central and accessible locations in the Bronx and in Brooklyn, while Manhattan is traversed near its backbone from end to end.

Next to the convenience and comfort of the numerous passengers, and the speed with which they are carried, the marvel to the individual is the cheapness of it. Two cents a mile is the current idea of the long haul steam railroads, while in the Subway, for whoever chooses, it is two or three miles for a cent. This cheapness of transportation, considering the distances traversed, is characteristic of all the systems of popular conveyance in New York. On some of the surface lines it is possible to ride for a single fare until one is, or should be, ashamed to ride any further, and on the elevated lines any one who is sufficiently informed may ride all day without challenge. Of course not many take advantage of this opportunity or could find any advantage to themselves in doing so, and the company is thus automatically protected from unlimited over-riding.

The complaint of overcrowding, which is always to be heard, and on practically all lines at some times of the day, would seem to be the unavoidable accompaniment of the low fares, the profits, whatever there may be, being all contributed by the strap-hangers. It is practically certain that no line in New York

could pay expenses if it gave everybody a seat at all hours of the day.

The benefits of urban and of interurban transportation are not all upon the individual passengers actually carried. Each one rides for a purpose other than the ride itself. The majority are workers of some class and are going to or from the places of their industrial activities. The workers of the trading, supervising or employing classes are working for others constantly and producing results to be shared by the many. The workers of the wage earning classes also are being transported for the benefit of their employers and of their employer's customers. So the many who seek only amusement and recreation, when they reach the places where these desirable are dispensed usually pay quite liberally for them and their visits leave large profits where they go.

The Subway may be considered as for the time reasonably adequate for its local traffic in the business and residence portions of Manhattan, but this is its minor function and also is largely provided for by other systems. Its real purpose and promise of relief was in its outreach beyond the congested areas, and for this its entire inadequacy is evident enough and must be emphasized by vast discomfort and inconvenience during the present summer. At the northern extremities of the system Van Cortlandt Park will be reached by one branch as Bronx Park with the magnificent "zoo" is already reached by the other, and the rush to these will be profitable to the management, so far as the crowding and overcrowding of trains bring the profit; but these profits will be much restricted by the insufficent capacity for handling and carrying the crowds.

But the most disappointing inadequacy of the Subway will be realized at the southern terminus of the line, Atlantic Avenue, Brooklyn. Here is effected the most intimate and perfect connection of all Manhattan and of all beyond it with the Long Island Railroad and all the magnificent and unlimited possibilities of suburban residence thereby afforded. Besides that, at this same point is now the best, shortest, cheapest and most available route to the popular seaside resorts: Coney, Brighton, Manhattan, Rockaway, Far Rockaway, Long Beach.

The incapacity of the Subway and its tunnels for conveying the inevitable crowds is self evident and much disappointment and dissatisfac-

tion must develop. Other lines which are planned will in time help the matter, but precisely where the present line is located is the best place for a large increase of capacity. This will entail of course large expenses, most of which would be covered by the great increase of receipts, but whether the additions would "pay" at once or later is not the only question, because there would be so many benefitted besides these actually carried, and these beneficiaries should in some way share the cost.

THE ELECTRIC AIR DRILL PARADOX

"At the last meeting of the Chemical, Metallurgical and Mining Society, Mr. T. Lane Carter made some interesting remarks in regard to electric rock drills—of which the Temple-Ingersoll type, it will be remembered, is the best known. Mr. Lane Carter admits that if an efficient electric drill could be found it would be a great blessing, but he does not believe there is much scope for a drill which is supplied by air compressed in the mine by an electric machine near by. The only places where such machines would be successful are in countries like the Western States or Italy, where there is enormous water power, and where electricity is very cheap. Until the Victoria Falls electricity gets here, he is of opinion that power will not be cheap enough on the Rand for such machines."

The above, from the latest-to-hand copy of the *South African Mining Journal,* is a good illustration of the ease and completeness with which the Electric Air Drill is misunderstood. The drill is not in the least an electric drill, and it is in no way related to the air operated drill as heretofore known. The little portable apparatus accompanying the drill proper is a pulsator, and is as much a rarifier of the air as it is a compressor, and the power required for equal work instead of being greater is only one-third to one-fourth, at the power house, of that required for any of the drills of the more familiar types. The drill is especially desirable where power is dear, instead of cheap.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The semi-annual meeting of The American Society of Mechanical Engineers will be held in Detroit, Michigan, June 23-26. An entire session will be devoted to papers on the con-

veying of materials, when hoisting and conveying machinery, including belt conveyers, the use of conveying machinery in cement plants, etc., will be discussed. Among other subjects which will be taken up by professional papers are, "Clutches," with special reference to automobile clutches, by Henry Souther: "Some Pitot Tube Studies" by Prof. W. B. Gregory, of Tulane University, New Orleans, La., and Prof. E. W. Schroder, of Cornell University; "Thermal Properties of Superheated Steam," by Prof. R. C. H. Heck, of Lehigh University; "Horse Power, Friction Losses and Efficiencies of Gas and Oil Engines," by Prof. Lionel S. Marks, of Harvard University; "A Journal Friction Measuring Machine," by Henry Hess, of Philedelphia; "A Simple Method of Cleaning Gas Conduits," by W. D. Mount; "A Rational Method of Checking Conical Pistons for Stress," by Prof. G. H. Shepard, of Syracuse, University; and "The By-Product Coke Oven," by W. H. Blauvelt.

A lecture on "Contributions of Photography to our Knowledge of Stellar Evolutions" will be delivered by Prof. John A. Brashear, of Allegheny, Pa. The usual receptions will be held and excursions will be made to manufacturing plants, the ship building yards and various points of interest in and around Detroit. Among the excursions planned is one to the University of Michigan, at Ann Arbor. The Gas Power Section of the Society will hold a session, and the Society for the Promotion of Engineering Education and the Society of Automobile Engineers will hold a meeting in Detroit at the same time.

The following will be read with interest in connection with the article by Mr. Rix which appears in the present issue:

Compressed air has become so important a form of motive power that any elucidation of the principles involved is bound to be interesting. And no one is better fitted to expound this subject than Mr. Edward A. Rix. It is 30 years since he and his partners, W. H. and John B. Reynolds, brought the Ingersoll drill to the aid of Adolf Sutro in the making of the great adit that drained the Comstock lode, and it is 30 years since Mr. Rix took the same drill to the Idaho mine at Grass Valley and replaced the old Burleigh machnes,

which weighed 600 pounds apiece, as against, say, 275 pounds for a drill of equal utility to-day. The Burleigh had just made a record in the Hoosac tunnel, a railway bore in Massachusetts, where this first machine-drill was invented about 1872.—*Mining and Scientific Press,* San Francisco.

QUESTIONS AND ANSWERS

T. D. P., Winnipeg, Manitoba. *Q.:* With electric current supplied at $12.50 per horsepower per annum—24 hours service—what would it cost to compress 10,000 cubic feet of free air per minute to 50 lbs. gage, assuming the barometric pressure to be normal, or 14.7 lbs? *A.:* The theoretical cost of compressing, adiabatically, 1 cubic foot of free air per minute to 50 lbs. gage, is 0.11952 horse-power and therefore the cost per 10,000 cu. ft. would be 1195.2 horse-power. If to this we add 25 per cent. for all losses in the compressor itself, friction, leakage, etc., the horse-power to be actually delivered to the compressor, and not taking into account any of the preliminary losses, will be 1494, which, at $12.50 per horsepower, amounts to $186,750.

E. R. S., San Francisco. *Q.* In your March issue you state the rule of the A. L. A. M., for estimating the horse power of gasolene engines to be the square of the cylinder diameter in inches divided by 2.5. Is there not some factor omitted? We would suppose that the length of the stroke would have much to do with the power. *A:* The rule was, we believe, printed correctly. It is of course only a rough-and-ready rule, better as a suggestion to guess by than a guide for accurate computation. The length of stroke would not cut much of a figure because the shorter stroke would imply the higher rotation and *vice versa.* Gasolene engines, especially in automobiles, are run at all sorts of speeds, and whatever the nominal horse power, by the above or any other rule, the actual might be double or one-half or almost anything. The presumption would generally hold that the larger the cylinder diameter the higher would be the horse power. Instead of dividing by 2.5 we would multiply by its reciprocal, 0.4, giving the same result.

P. P., Helena, Montana. *Q.:* I wish to secure some data on the lifting power of compressed air of various degrees of compression, the object being to lift from 2 to 4 cu. ft. of water per

second to a height of 200 feet—not necessarily a vertical lift; a favorable incline can be had—for purposes of irrigation. Hydraulic rams to do this would be too expensive and to secure compressed air by compressors would also be too expensive. The plan would have to be along the lines worked out by Mr. W. O. Webber on the Maine Coast. Ditch construction is not practical, but it is practical to secure considerable fall for the purpose of compressing air on the plan referred to.

A.: There is no way ever devised which will dodge the expense in a case like this. It should be noted that in the description of the Webber tidal air compressor in our March issue the estimated cost of the construction was $100 per horse-power. The Taylor system which uses falling water for compressing air also costs quite an amount for the necessary excavation, piping, etc, this varying largely with the location and other conditions. The theoretical power required in the case cited by our correspondent would be: 4 cu. ft. per sec. x 60 sec. x 62.5 lbs. per cu. ft. x 200 ft lift÷.33000= 90.9, say 91, horse-power. Allowing for all losses, both with the water and the air, probably nearly double this power would be required at the beginning of the series. As to the best plan in this specific case we are unable to advise without more knowledge of the situation.

PNEUMATIC RIVETING HAMMERS IN BOILER WORK

The following question, with answers from two boiler making firms, appeared in *The Boilermaker:*

Q.—Can you give me an idea of the character of work done with pneumatic riveting hammers driving ⅞-inch rivets in ½-inch sheets in the shells of steam boilers carrying 125 pounds pressure? Do they fill the holes and make good steamtight work? If so, what size hammers are generally used for this size of rivet. We have tried a 6-inch stroke hammer, but it did not fill the holes properly.

H. A. F.

A.—The work you describe is done every day and very satisfactorily, too, in many shops, but a 6-inch stroke hammer is not the proper size, as it will not develop sufficient power. We would recommend a hammer which has a piston diameter of 1⅛-inch by 9-inch stroke, and if operated under an air pressure of from 80 to 100 pounds per square inch, we are sure ⅞-inch rivets can be driven steam-tight.

D. P. T. Co.

If you have an air pressure of from 90 to 100 pounds per square inch, and the rivets are properly heated their entire length, using a pneumatic hammer having a piston 1 3/16-inches diameter and 8-inch stroke should make absolutely tight work, filling the holes as well as it is possible to fill them under any other system of riveting.

We note you say you have tried a 6-inch stroke hammer. While a 6-inch stroke hammer is used very extensively for structural work, we would not recommend a 6-inch stroke hammer for driving steam-tight work on rivets larger than ½ inch. You are doubtless aware that a pneumatic riveting hammer may show very satisfactory results driving rivets on structural work and yet fail to make steam-tight work on boiler work. A little experimenting will show that the degree to which the rivet is staved in the hole depends very largely upon the weight of the striking piston. While in the ordinary hand riveter for structural work the piston is 1 1/16 inches in diameter, a class of riveters with pistons 1 3/16 inches in diameter is, by virtue of the heavier piston, particularly adapted to steam-tight work. P. P. T. Co.

NEW BOOKS

Telephone Construction, Installation, Wiring, Operation and Maintenance, by W. H. Radcliffe and H. C. Cushing, Jr., The Norman W. Henley Publishing Company, New York, VIII +172 pages, 4¼ by 7 inches, 125 cuts. Price, $1.00.

This is not a learned book by and for the college professor but is for "the amateur, the wireman or the engineer who desires to establish communication between the rooms of his home office or shop; between his house and shop; between his home and the homes of his friends; or between his shop and some distant building." Everything is made plain and clear without any waste of words, and the book has no padding.

TRADE PUBLICATIONS

Light Locomotives, Tenth Edition, H. K. Porter Company, Pittsburgh, Pa. 224 uages, 6x9 inches. This handsome catalogue com-

pares with its predecessors as the present plant of the company compares with its earlier installations. The annual capacity has increased from 20 to 400 locomotives, and since the immediately preceding edition we are assured that the progress, in the increased power and efficiency and in the quality of output has been far greater than during any similar period before. Only steam locomotives, but these in astonishing variety, are treated of in this publication and in addition there are about 80 pages of valuable tables, data and suggestive railroad information.

OILING AIR DRILLS

The following is from an article by Mr. Claude T. Rice in *The Engineering and Mining Journal*. It has the supreme merit of being readable and interesting. The matter of lubrication we believe, however, is not ignored by the builders of the drills to the extent suggested, and whoever will may properly oil his drill by means already provided, at least by the most responsible and experienced drill manufacturers.

The air drill is the most abused machine in use about mines, for it is supposed to be able to stand all kinds of rough usuage. No one seems to have any real respect for the air drill, although many discuss the merits of one machine over another. The miner, seeing a machine whose interior parts are as well finished as the interior of a steam cylinder, furnished to him without any provision for oiling, naturally forms a sort of contempt for it and decides that it can stand any treatment; therefore he acts accordingly. He hammers the machine in his rage when a hole becomes fitchered, although a little shifting of the machine on the arm or a little raising or lowering of the arm on the bar might have saved the hole. Of course such treatment of a machine is foolish, but when I hear some person ascribing high repair bills entirely to the "fool" machineman, I often wonder who is the fool; the miner, who hammers the drill with a "double-jack," or the man with the T-square in the designing room, who is spending all his time on improving the construction of the valve, the piston, the ports and other such refinements, so that he cannot find time to devise an efficient means of lubricating the machinery.

Of course the man with the T-square says that there is no use in designing a means of oiling a machine that works under such conditions; the oil, he says, will only cause dust to stick more readily to the moving parts and cause them to cut. But the air in a raise is no dustier than the air near rolls that are crushing dry ore, and no one advocates the non-lubrication of such rolls.

In present mining practice, at least in the Western camps of the United States, the air drills that are oiled six times a shift are like the dodo bird, hard to find. The machineman, as soon as he has rigged up and connected the hose, pours some oil in the valve, tells the helper to stand back, starts the machine, and blows oil all over the stope. The drill is then generally considered to be properly lubricated until noontime; after lunch the drill gets another "dose of oil," and the stope a second coat.

The oil is generally kept in a tomato can; half the oil is spilt in the stope, and the half that is used is soon heavily laden with rock particles. Sometimes a miner, more careful than his mates, will bring from home an empty syrup can. Such a can makes a good oil can, provided it is stoppered after using and provided also it is placed at blasting time in some place where it will be safe from puncture by a flying rock.

Some companies, becoming impressed with the great waste of oil, try to remedy the difficulty by furnishing an iron oil can to the miner. But as the company charges the miner 50c. for the oil can until he returns it, the miner reluctantly receives the can, for he knows sooner or later that he will lose it. Finally the can is lost and the miner spends 50c. worth of his time hunting for the can, and, in case a wrangle arises through his accusing some other miner of stealing or hiding the can, a good deal more time (and possibly some blood) is lost. The result is that by using this can, which is no better than the old syrup can, a lot of valuable time is lost in hunting for the can when it is lost. The company thinks that the miner pays for the lost can, and so he does, but the company also pays, considering the time that is lost. The trouble is not in the oil can; it is in the method of lubricating the drill. Any can (but not any bottle) that keeps dust out of the oil is good enough. The remedy is not in buying iron oil cans, but in insisting that the manufacturers devise some efficient lubricator to go with their air drills.

COMPROMISING IN MINE PIPING

In the Journal of the Transvaal Institute of Mining Engineers, Mr. E. J. Laschinger offers the following suggestions:

The considerations involved in a study of economy of air transmission in mines raises the larger question as to whether it may be advisable to modify current practice of air compression on the Rand, at least in certain cases. Would it not be better to increase the pressure of air delivered by the compressors in the case of the deep-deeps rather than go to the great extra expense of putting in very large, long air mains? There may be certain cases also where existing mains are up to the economic limit in size, and satisfactory pressures underground would be obtained more cheaply by slightly raising the pressure at the surface than by installing new and expensive mains. This is an important matter for detailed investigation. If in any part of the system the pipes are smaller than economic transmission considerations indicate, the sizes should be increased, but if that limit has been reached, the other alternative appears to offer the proper solution.

Another argument against installing rather large mains in case of mines is that the air will be delivered only at its maximum distance from the compressors toward the end of the life of the mine. During the first years the loss of pressure for the shorter lengths will be proportionately small, and if towards the end of the life of the mine the pressure loss be found to very adversely affect the working of the drills, it would probably again be more economical to slightly raise the pressure at the compressor than to have a large capital sum lying unremunerative for years. There is a tendency at present among mining men and engineers on the Rand to go in for large sizes of mains, and it may not be unnecessary to say a word of caution against going to extremes. If poor pressures obtain underground it is advisable to find out where the trouble lies, and what are the best remedies. Are the pipes leaking badly; is the main too small; or are the distributing pipes too small and badly laid; and, further, would anything be gained by raising the pressure at the compressor delivery? These four aspects of the whole question need each to be separately considered and investigated.

F OR A COMPRESSED AIR WATER SERVICE

BY J. W. LAWRENCE.*

Out in the country, where one is away from the water mains of a city and cannot be attached, it is a source of much satisfaction to have a water supply on the premises that answers as well in many respects as the city system. To have a liberal supply of hot and cold water on tap in the house wherever you please, upstairs, downstairs, or in the cellar, to have hydrants in the barn or stock yards, similar to those in the house yards in town, from which water may be drawn for the stock, or to which a hose may be attached for washing buggies, sprinkling lawns, or other purposes, is possible under a system which has gradually been finding its way into popular favor. This system has nothing to do with the quality of the water; it is simply a system for delivering water already on the premises in well, cistern, or reservoir. It is proposed by this system to force the water through the pipes by means of compressed air. The house is piped in the same manner as if it were in the city and connected to the city mains. If it is desired that hydrants be placed about the yards, barns or outbuildings, they may be put underground in the same manner as in the city, say four feet deep, to keep them from freezing. If there are flower beds or lawns to be sprinkled, a hose may be attached to one of the hydrants at any time. The same hose may be used for fire purposes. With this system, some householders have a suitable hose bibb in the house, with a line of hose coiled and hung up ready at hand for use at any time. A windmill, gasoline engine, or some such pumping arrangement, is necessary at the start. Now, someone will say that you can have the supply thus far described by means of an elevated tank in connection with the windmill; so you can, but I believe the compressed air system much better.

An air-tight steel tank is part of the cellar of the house, and may be as large as the owner may choose to purchase. There are manufacturers who make them specially for this purpose. If a windmill is used for pumping, then the water is forced by the windmill pump through pipes into the steel tank. The pipes

*Professor of Mechanical Engineering, Colorado Agricultural College, Fort Collins.

are put underground out of reach of frost. Some who have adopted this plan have a gasoline engine attached and ready for use, so that if the air is still, and the windmill fails to pump enough water, the gasoline engine may be used in such an emergency.

Water having been pumped into the tank and the tank now being partly filled, an air-pump attached to the tank, and having a long lever worked by hand, is operated for a few minutes, and compressed air, under strong pressure, is put into the tank with the water and will force it out to the last drop at any point in the system of piping, and to a height within the forcing power of the compressed air.

There are many disadvantages in the use of the elevated tank, either outdoors or indoors; if outdoors, it gets frozen in cold weather, as will also the exposed pipe connected with it. Then there is the likelihood of dead birds, bugs, leaves, dust and rubbish getting in, and in summer the water is apt to get very warm. If indoors, the elevated tank may freeze, or perhaps leak and damage the building. The possibility of an elevated tank falling down and doing much damage is sometimes present.

The compressed air water supply is free from the objectionable features mentioned above. The water remains at a desirable temperature, winter and summer; is kept perfectly clean in the tank if delivered to it in a clean condition. The air in the tank mixes somewhat with the water and helps to aerate it, keeping it sweet and clean. There are now manufacturers who can supply these outfits suited to a small house or a great building.

AN AIR PLUG DRILL CUTS A HOLE THROUGH A CONCRETE DAM

An interesting piece of concrete cutting by means of $1\frac{1}{2}$ in. flat chisels used with a compressed air plug drill was accomplished at Ithaca, N. Y., last summer, the work being described by Prof. Ernest W. Schoder, of Cornell, in a recent issue of *Engineering News*.

The problem was to cut through a ten-year old concrete dam a circular hole for a flood wasteway, at the upstream end of which it was intended to place a 60-in. sluice gate. The dam is on Fall Creek and forms the 20-acre reservoir utilized by the hydraulic laboratory and by the hydro-electric power plant of Cornell University.

The stone in the concrete is crushed shale, and the cement used a mixture of Rosendale and Portland. The concrete seemed to be soft and tough rather than hard and brittle. On account of the difficulty of drilling holes in concrete of this texture the plug and feather method was not feasible, and with the air drill the rapid action of the tool made it almost impossible to prevent it from sticking. Chipping by 1-in. flat chisels did not work satisfactorily, but the wider $1\frac{1}{2}$-in. chisels seemed to be suited to the material.

The thickness of the dam is 16 ft. where the hole was cut, the invert being $2\frac{1}{2}$ ft. above the rock creek bottom. The hole is $5\frac{1}{3}$ ft. in diameter for the downstream 13 ft. of its length, and 6 ft. in diameter for the last 3 ft. near the upstream face of the dam.

The hole was cut at an average rate of exactly 1 ft. per day of nine hours, using a single drill with air at 70 lbs. pressure. Two Italian laborers alternated in holding the drill. A liberal supply of sharp chisels was kept ready so that there was no deplay. The chisels were sunk into the concrete until the repeated blows of the plug drill hammer caused a piece to break out. A few seconds to five or ten minutes were necessary to break out a piece of the concrete. As the men became accustomed to the drill they used at times a wedging method by sinking two or three chisels into the concrete along a line calculated to loosen a large piece containing perhaps $\frac{1}{2}$ cu. ft. of material. This worked well, especially when the lower portion of the hole was advanced ahead of the upper portion. No water leaks were encountered. When the cutting approached within 1 ft. of the face of the dam, the reservoir was emptied through the laboratory canal.

ROCK EXCAVATION ON THE CLYDE

The deepening of the Clyde Channel to a minimum of 28 ft. below low water of the spring months was completed last year, by the removal of rock from the Elderslie reef over an area of $5\frac{1}{2}$ acres. The removal of this reef was started in 1886 when the minimum depth at low water was only 14 ft. The channel was deepened to a minimum of 20 ft. by the removal of 110,000 tons of rock. In 1903 it became necessary to further increase the depth of the channel and contracts were let

to Messrs. W. Hill & Co., London, for the removal of an additional ledge of 8 ft. In order to locate the work two parallel rows of poles about 300 ft. apart were set up on base lines on the bank of the river, the poles in each row being on 25-ft. centers. At first the drilling of the rock was accomplished from a barge within which was a caisson that could be lowered and raised by steam winches. The caisson was large enough to accommodate six or seven men, and contained six Ingersoll-Sergeant compressed-air rock drills. When at work in the river, the position of the barge was regulated from the bearings of the poles or stakes already described on the south bank, and its distance from the base line was measured by means of a wire rope with marks every ten feet, wound or unwound as required by a reel on the deck of the barge. Owing to the difficulty of steadying the caisson on the uneven bottom, and the limit to the lengths of the boring rods which could be used in the caisson, this mode of working was found to be unsuitable, and the contractors provided barges equipped with Ingersoll percussion drills suspended along one side of the barge by chains passing over pulleys on the top of an iron frame-work. The drills were slung in guiding frames, leaving them free to move up or down as required, but not laterally. The boring operations in the earlier stages had been carried out in patches, careful record of which was kept on charts both by the contractors and the engineer of the Clyde Trust, but later it was decided to conduct all the boring and blasting operations in belts, as had been adopted in the former contract of 1886. The belts covered a width of 15 ft. with six rows of holes in each belt. These rows were 2½ ft. apart, and the holes, which were spaced 5 ft. apart longitudinally, were opposite each other in the alternate rows. This mode of working provided a free side or face, and allowed the dredger to follow the boring barge and lift the broken rock, and clean up the surface of the next belt to be bored. For the most part the depth of rock had to be bored, blasted, and dredged in at least two breaks or depths. Under this system the work progressed much more rapidly, and, as the boring was carried to a depth of 30 ft. to 31 ft., below low water, dredging was easily accomplished to the desired depth of 28 ft. below low water. In order to be certain that the minimum depth was secured throughout, a diving bell went over the entire bottom. During the contract 38,240 holes were drilled to an average of 6 ft. The dynamite was lowered into the holes enclosed in a zinc canister. The total amount of rock removed was 340,520 long tons.—*Engineering Record.*

A SOFT TUNNEL CONTRACT

An old mining man remarked yesterday that he was once interested in a tunnel which was a very profitable venture for a friend of his in Colorado. "Railroading in my section of the country at that time," he remarked, "was primitive, but for some reason or other an urgency contract was left for the building of a tunnel in midwinter between our town or camp, as you might call it, and a point about a mile and a half distant. My partner got the contract, and he was very mysterious about it. He arranged the terms so that because of the alleged character of the work he was to get $40 a foot. I could go into details with regard to the preliminaries, but suffice it to say that within a certain specified time, unusually short, as a matter of fact, he sent for the engineer representing the company making the contract to pass on the work. It went through all right, and was approved. Now that seems all right, but as a matter of fact my friend "Gassy," as he was called, had built a tunnel through a snow mountain, put in timbers to support the weight of the snow, covered the exterior snow with dirt and mud, and decamped with the check which the fool company gave him.—*New York Times.*

AERIAL NAVIGATION TERMS

The following terms have been adopted and authorized by the Permanent Aeronautic Commission:

Any machine without a gas vessel or bag is to be called an "Aeronef," and this type is further to be divided into three sub-divisions, called Helicopters, Aeroplanes, and Orthopters. The first is an aeronef relying on one or more propellers for its suspension and progress through the air; the second is an aeronef in which suspension in the air is more particularly assured by one or more planes, and the third is an aeronef sustained and propelled by beating wings. The term aviator is to be employed

as defining the operator of any of these types. Aeronaut will be applied only to the pilot of an aerostat or aeronat. The aerostat is a common balloon, floating along with the wind, and the areonat is a dirigible balloon.

NOTES

It's just as we have said time and again. Cutting the price never increases the demand by even the most insignificant fraction. That is all the more reason why a short demand should be supplied at a good round profit. *Rock Products.*

The H. W. Johns-Manville Company, fireproofing and non-conducting materials and electrical supplies, will open a new branch in Detroit, 72 Jefferson Ave., under the management of Mr. Willard K. Bush, formerly of the Milwaukee branch. A complete stock of goods will be carried.

The traction power used in anthracite mines depends directly upon the condition of the haulage roads. In a certain mine where mules hauled the coal the cost of transportation was from 9 to 11 cents per net ton mile. In most mines where compressed air locomotives are used and the grades are not too heavy the cost of haulage per ton mile does not often exceed 3.5 cents.

The two hundred and twenty-fifth anniversary of the founding of Philadelphia is to be celebrated in October. The city has 15,887 separate manufacturing establishments costing $476,500,000. The employes number 246,445, earning annually $112,000,000 in wages. The raw materials cost $327,000,000 and the value of the annual product is $603,500,000. There is a jobbing and wholesale trade of $500,000,-000 annually.

The growth of the acetylene industry and the safety with which the gas may now be used has led to a modification of the insurance rules relating to it. Hitherto the rules formulated by the National Board of Fire Underwriters prohibit the installation of an acetylene generator in an insured building. At a recent meeting, however, the Board, after considering various reports on the condition of the

acetylene industry decided to strike out from its rules such words as prohibited inside installation of acetylene generators, and substitute the following: "Generators, especially in closely built-up districts, should preferably be placed outside of insured buildings in generator houses constructed and located in compliance with Rule 9."

The Chicago Railways Company, which owns all of the North Side and West Side street railways in the city of Chicago, has just awarded a contract to the National Brake and Electric Company, Milwaukee, Wis., to furnish all of the air-brake apparatus for the 1,200 new cars, which, in accordance with the traction ordinance, it will purchase and place in service within the next three years. The company expects to put about 550 new cars into service this summer, orders for 400 cars having already been placed with the car builders. This contract, it is believed, covers a larger number of air brakes than has ever before been contracted for by any electric-railway company.

In a recent discussion before the Société de l'Industrié Mineralé, M. Reumaux describes his experience with drill bits. Most of the French bits have six-pointed faces, while certain American bits have eight points. His tests have led him to adopt the eight-pointed bit. While the cutting face of the eight-point bit is necessarily larger, involving thereby the drilling of larger holes, the consumption of steel is much less, and the rate of advance is no slower than with the six-pointed bit. Referring to the sharpening of star-faced bits, Mr. Roumeux objects to the use of the swage furnished by the drill makers. He maintains that, while the swage affords a rapid method of forming the bit face, the cutting edges are neither sharp nor durable, and he advocates a return to hand dressing in order to get better results from drills.

LATEST U. S. PATENTS

Full specifications and drawings of any patent may be obtained by sending five cents (not stamps) to the Commissioner of Patents, Washington, D. C.

APRIL 7.

883,696. HYDRAULIC AIR AID GAS COMPRESSOR. GEORGGE P. CARROLL, Bridgeport. Conn.

883,730. DRILL. JOHN F. MITCHELL, Topeka. Kan.

883,814. AIR-BRAKE HOSE-COUPLING. JOSEPH E. LaRocque, Nomininque, Quebec, Canada.

883,858. THRUST BORING - MACHINE. CHARLES CHRISTIANSEN, Gelsenkirchen, Germany.

A boring machine provided with a cylinder, an inclosed piston, a pair of compressed air inlet ducts communicating with opposite ends of the cylinder, a flap valve fulcrumed at its centre of gravity and controlling both of said ducts, a pair of exhaust ports in the cylinder adapted to be alternately uncovered by the piston, and a boring bit operable by said piston, substantially as specified.

883,888. AIR OR GAS COMPRESSOR SYSTEM. HULDREICH KELLER, Berlin, Germany.

883,918. AIR-BRAKE SYSTEM. ULYSSES S. SMITH, Sacramento, Cal.

883,928. VALVE FOR AIR-COMPRESSORS. ASA F. BATCHELDER, Schenectady, N. Y.

883,936. HYDRAULIC AIR-COMPRESSOR. JOSEPH H. CHAMP, Cleveland, Ohio.

883,951. APPARATUS FOR HEATING AIR. FRANCIS W. GREEN, Wakefield, England.

884,016. PNEUMATIC CONVEYER. CLARENCE L. GROVES, Hartford City, Ind.

884,024. MECHANICAL BALL-THROWER, ROBERT H. LAKE, Washington, D. C.

884,042. MEANS FOR PRODUCING MOTIVE FLUID FROM THE COMBUSTION OF FUEL. WILLIAM J. BENSHAW, Newcastle, England.

1. An apparatus for generating a motive fluid to be used expansively in a separate motor or motors consisting of a series of cylinders arranged around a common crank shaft in which cylinders moist air is compressed, a reservoir adapted to receive the compressed air from all the compression cylinders, a series of combustion cylinders also arranged around said crank in which oil and air or other combustible is burned and into which the compressed air from said reservoir passes for the purpose of extracting therefrom the heat due to combustion, said cylinders being provided with pistons and inlets, outlets, pasages and valves by means of which the oil and air or other combustible, the air to be compressed and the compressed air are admitted into the two series of cylinders and the compressed air conducted from the compression cylinders into the reservoir and from
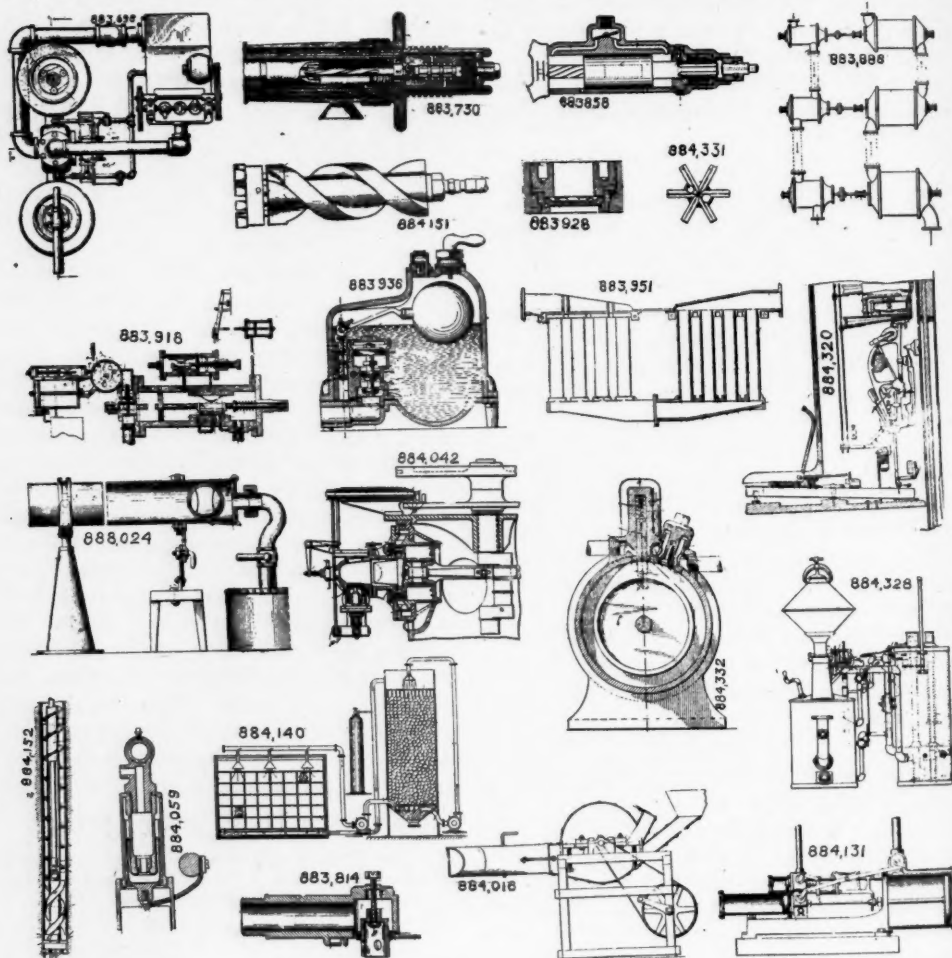
the reservoir into the combustion cylinders, mixed with the products of combustion and passed into a pipe or trunk common to all the combustion cylinders, from which the mixture may be drawn off as required substantially as described herein.

884,049. PNEUMATIC HOLDER FOR COMMUTATOR-BRUSHES. CHARLES W. SPIERS, Battersea, London, England.

884,131. MOTOR-DRIVEN EXHAUSTER AND COMPRESSOR. MELVIN D. COMPTON, New York, N. Y.

884,140. PROCESS OF KEEPING AQUATIC ANIMALS ALIVE DURING THE TRANSPORTATATION. GEORGE ERLWEIN, Berlin, and ERNST MARQUART, Charlottenburg, Germany.

1. The method of keeping aquatic animals alive during transportation, which consists in surrounding them with a moisture-retaining packing and supplying a moisture laden oxygen-containing gas .

884,151. PNEUMATIC HAMMER. MARTIN HARDSOGG, Ottuumwa, Iowa.

884,152. PNEUMATIC HAMMER. MARTIN HARDSOGG Ottumwa, Iowa.

884,320. Manually and PNEUMATICALLY OPERATED PIANO. JOHN W. DAVIS, Pulaska, Tenn.,

884,328. ACETYLENE-GENERATOR. NELSON GOODYEAR, New York, N. Y.

884,331. PNEUMATIC AND OTHER DRILLS. MARTIN HARDSOGG, Ottumwa, Iowa.

884,332. COMPRESSOR. BERT E. HILL, Pittsburg, Kans.

APRIL 14.

884,364. COMPRESSED-AIR BRAKE. ALFRED CHANDERSON, Jette St. Pierre, Belgium.

884,419. STONEWORKING-TOOL. CHARLES B. RICHARDS, Cleveland, Ohio.

884,432. AEROPLANE. MELVIN VANIMAN, Genevilliers, France.

884,522. APPARATUS FOR AUTOMATICALLY DISCHARGING LIQUIDS. ALBERT PRIESTMAN, Philadelphia, Pa.

884,548. FLUID-ACTUATED VISE. THOMAS F. WARWICK, Metter, Ga.

884,694. AIR-BRAKE. WILLIAM A. WEANT, Mocksville, N. C.

884,841. VALVE FOR FIRE-SPRINKLER SYSTEMS. JAMES B. McGINLEY, Allegheny, Pa.

884,971. PNEUMATIC TOOL. CHESTER B. ALBREE, Allegheny, Pa.

884,990. METHOD OF CONSTRUCTION. JAMES C. MEEM, Brooklyn, N. Y.

1. A method of building a pneumatic caisson for excavation, which consists in driving side walls from above below the level of the water, building a fixed roof thereon, and extending the sides from the forward end as the excavation proceeds.

APRIL 21.

885,011. AUTOMATIC VACUUM CLEANING APPARATUS. WILLIAM J. BERGENS, Pittsburg, Pa.

885,044. TUNNELING-MACHINE. WILLIAM J. HAMOND, JR., Pittsburg, Pa.

885,137. AIR-PURIFYING APPARATUS. WILLIAM G. R. BRAEMER, Buffalo, N. Y.

885,169. PNEUMATIC BRAKE. WILLIAM H. MILLER, Cleveland, Ohio.

885,301. AIR-PUMP. JOHANN W. SIEPERMAN, and EMIL FUDICKAR, Elberfield, Germany.

885,319. APPARATUS FOR THE COMPRESSION OF GAS OR AIR FOR LAMPS. WILLIAM H. CHIPPERFIELD, London, England.

885,361. ACETYLENE - GENERATOR. IRA MUMMA, Dayton, Ohio.

885,361. AIR-PUMP FOR STREET-CARS AND ANALOGOUS PURPOSES. WILLIAM A. COLLINS, and WILLIAM WESTERBROOK, Detroit, Mich.

885,485. AIR-PUMP. GEORGE W. KELLOGG, Rochester, N. Y.

885,537. PNEUMATIC-TOOL RETAINER. EDWARD J. SHOFFNER, Roanoke, Va.

APRIL 28.

885,737. PNEUMATIC VALVE. GUSTAVE F. DOHRING, Cranford, N. J.

885,783. ROTARY COMPRESOR. CASSIUS C. PALMER, Cranford, N. J.

885,812. PRESSURE-REGULATOR. JOHN E. WARD, New York, N. Y.

885,844. WINDMILL-REGULATOR. LYMAN S. HAGERMAN, Mondamin, Iowa.

885,877. AIR-COMPRESSOR. JOSEPH T. SIMSON and THOMAS LISHMAN, Durham, England.

885,985. PNEUMATIC TOOL. HARLEY M. DUNLAP, Battle Creek, Mich.

886,054. METHOD OF WORKING EXPANSION ENGINES. FRITZ HILDERBRAND, Deutsch Wilmersdorf, Germany.

1. The method of working an expansion engine, consisting in supplying the working cylinder with liquefied gas and compressed air, and allowing the mixture to expand, substantially as described.

2. The method of working an expansion engine, consisting in supplying atmospheric air to the working cylinder, and compressing it by means of the piston, and thereupon admitting liquefied gas into the said cylinder, and allowing the mixture to expand, substantially as desribed.
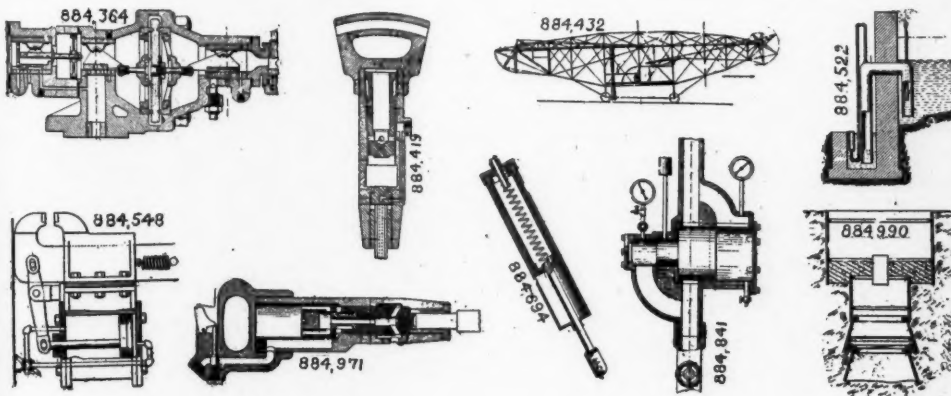
PNEUMATIC PATENTS, APRIL 14.
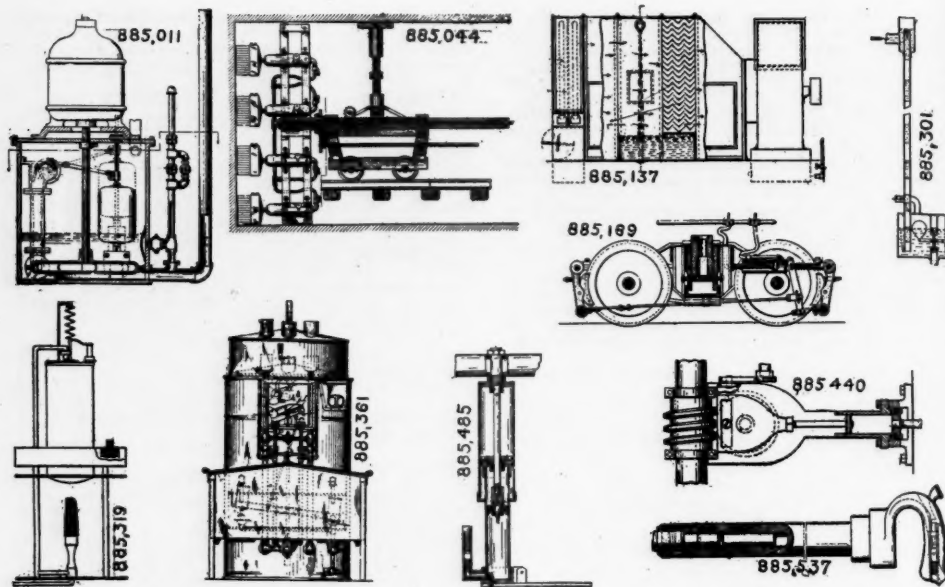
PNEUMATIC PATENTS, APRIL 21.

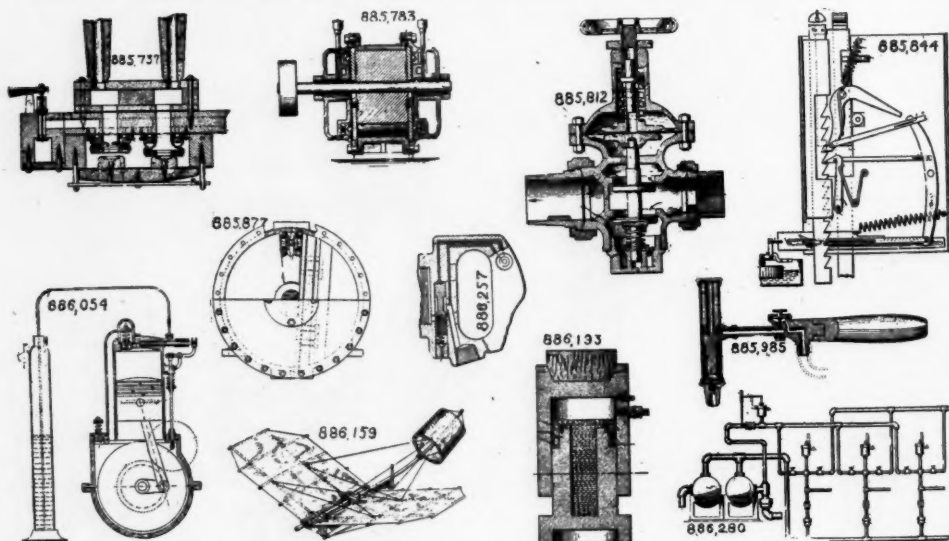886,159. AERIAL APPARATUS. MATTHEW B. SELLERS, Baltimore, Md.

886,193. COMPRESSED-AIR-CUSHION BLOCK. CLINTON C. DE WITT, St. Louis, Mo.

886,257. CONTROLLING MECHANISM FOR PNEUMATIC TOOLS. CHARLES H. SERGEANT. Brooklyn, N. Y.

886,280. APPARATUS FOR FORCING FLUID FROM WELLS. JOHN W. WAITZ, Oil City, Pa.

1. In an apparatus for forcing oil from wells, the combination of a single pocket arranged at or near the bottom of a well, an air supply pipe and an oil discharge pipe leading into said pocket, and an air compressing device comprising a plurality of cylinders, one of which is connected with the open air and the other or back pressure cylinder is connected with the air supply pipe, whereby the air remaining in the pocket after the oil has been discharged therefrom may be utilized by being delivered into said back presure cylinder, substantially as described.

PNEUMATIC PATENTS, APRIL 28.